UNCLASSIFIED

AD 296 016

Reproduced by the

ARM D SERVICES TECHNICAL INFORMATION AGENCY ARLINGTON HALL STATION ARLINGTON 12, VIRGINIA



UNPLASSIFIED

Best Available Copy

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

296 016

Publication No. U-1929

RESEARCH LABORATORY

ANNUAL TECHNICAL REPORT

INFRARED RADIATION EMITTED BY HOT GASES AND ITS TRANSMISSION THROUGH SYNTHETIC ATMOSPHERES

Prepared for

Advanced Research Projects Agency

The Pentagon

Washington 25, D. C.

Under Contract:

NOnr 3560(00)

Prepared by:

Darrell E. Burch David A. Gryvnak

31 October 1962

TISIA

"Reproduction in whole or in part is permitted for any purpose of the United States Government."

ABSTRACT

Measurements of the infrared emission of $\rm CO_2$ and $\rm H_2O$ near 3700 cm⁻¹ and near 2350 cm⁻¹ have been made at 900°K, 1200°K and 1500°K with pressures varied between approximately 5 and 1500 km Hg. Samples were contained in a sample cell 7.75 cm long and heated by molybdenum wire furnace. Investigations were made of absorption of radiation from hot $\rm CO_2$ by cold $\rm CO_2$ and compared with the absorption of radiation from a continuous source. Results of the measurements are presented in considerable detail in tables and figures.

TABLE OF CONTENTS

	Section		Page
Ī			
·•	ı	INTRODUCTION	1-1
•		General Discussion	1-1 1-2
•	2	EXPERIMENTAL	2-1
•		Apperatus	2-1 2-8
		Reduction and Presentation of Date	2-9
		Errors and Accuracy	2-11
	3	RESULT: EMISSION BY HOT CO	3-1 3-19
•	4	RESULTS: EMISSION BY NO. H20	4-1
•	5	TRANSK: JION OF RADIATION FROM HOT CO, THROUGH C'10 CO,	5-1 5-1 5-4 5-8 5-11
•	6	REFERENCES	6-1
•	Appendix A	FURNACE AND SAMPLE CELL	A-1
•	Appendix B	GAS HANDLING SYSTEM	3-1
•		DISTRIBUTACO	D-1

LIST OF TABLES

Table No.	Title Resolution Schedules				
2-1					
3-1A	Data	for	Samples	F1, F2, F3, F4, F5, F6, and F7	3-21
3-1B	Data	for	Samples	F8, F9, F10, F11, F12, F13, and F14	3-22
3-1C			•	F15, F16, F17, F18, F19, F20, and F21.	3-23
3-1D			•	F22, F23, F24, F25, F26, F27, and F28.	3-24
3-1R				F29, F30, F31, F32, F33, F34, and F35.	3-25
3-1F				F36, F37, F38, F39, 140, F41, and F42.	3-26
3-1G				F43, F44, F45, F46, F47, F48, and F49.	3-27
3-1H			•	F50, F51, F52, F53, F54, F55, and F56.	3-28
3-11				F57, F58, F59, F60, and F61	3-29
3-2A	Data	for	Samples	T1, T2, T3, T4, T5, T6, T7, T8, and T9	3-30
3 · 2B			•	T10, T11, T12, T13, T14, T15, T16, T17,	
			•	and T18	
3-2C	Data	for	Samples	T19, T20, T21, T22, T23, T24, T25, T26,	
				and T27	
4-1	Data	for	Samples	W1, W2, W3, W4, W5, W6, W7, W8, W9,	
			-	VIO. and VII	4.7

LIST OF FIGURES

Fig. No.	<u>Title</u>	Page
2-1	Optical Diagram of Apparatus	2-2
3-1	Emissivity Curves for Samples F1, F2, F3, F4, F5, F6, F7,	
3-2	F8, and F9 Emissivity Curves for Samples F10, F11, F12, F13, F14,	3-3
3-3	F15, F16, and F17 Emissivity Curves for Samples F18, F19, F20, F21, F22,	3-4
	and Y23	3-5
3-4	Emissivity Curves for Samples F24, F25, F26, F27, F28, and F29	3-6
. 3-5	Emissivity Curves for Samples F30, F31, F32, F33, F34,	
	F35, F36, and F37	3-7
13-6	Emissivity Curves for Samples F38, F39, F40, F41, F42, F43, F44, F45, and F46.	3-8
3-7	Emissivity Curves for Samples P47, P48, P49, P50, P51,	
3-8	F52, F53, and F54	3-9
	F60, and F61	3-10
3-9	Emissivity Curves for Samples Tl, T2, T3, T4, and T5	3-11
3-10	Emissivity Curves for Samples T6, T7, T8, and T9	3-12
3-11	Emissivity Curves for Samples T10, T11, T12, and T13.	3-13
3-12 3-13	Emissivity Curves for Samples T14, T15, T16, T17, and T18 Emissivity Curves for Samples T19, T20, T21, and T22	3-14
3-14	Emissivity Curves for Samples T23, T24, T73, T26, and T27	3-15 3-16
3-15	fe(v)dv for the 2350 cm ⁻¹ Region Versus the Total Pressure	
	for Samples Having Constant Mixing Ratio	3-17
3-16	fe(v)dv for the 2350 cm Region Versus the Total Pressure	
	for Samples Having Constant Values of Optical Thickness .	3-18
4-1	Emissivity Curves for Samples W1, W3, and W5	4-2
4-2	Emissivity Curves for Samples W2 and W4	4-3
4-3	Bmissivity Curves for Samp' We and W8	4-4
4-4	Emissivity Curves for Sarq 47	4-5
4-5	Emissivity Curves for Samples WO. WIG. and Wil	4-6

LIST OF FIGURES (CONT.)

Fig. No.	<u>Title</u>				
5-1	A Simple Hodel Showing the Effect of Coincident Lines	5-2			
5-2	Comparison of $T_{c}(v)$ with $T_{c}^{*}(v)$ for Case of Emitting and Absorbing GEs at Low Pressure	5-9			
5-3	Comparison of $T_C(v)$ with $T_C^*(v)$ for Case of Emitting Gas at High Pressure and Absorbing Gas at Low Pressure .	5-1			
5-4	Comparison of $T_C(v)$ with $T_C^*(v)$ on the Low Frequency Side of 2350 cm ⁻¹ CO ₂ Region	5-1			
5-5	Comparison of $T_C(v)$ with $T_C^*(v)$ for CO_2 in the 3700 cm ⁻¹ Region	5-1			
A-1	Diagram of Furnace and Sample Cell	A-2			
B-1	Diagram of Gas Handling System	B-2			

SECTION 1

INTRODUCTION

General Discussion

More fundamental information about the emission of infrared radiation from flames and its transmission through the atmosphere is clearly needed. The objective of the present experimental investigation is to provide basic information about the emission of CO, and H₂O, the two most important constituents of flames, and a but the transmission of the emitted radiation through atmospheric paths containing these same two species. A typical flame shows a region of strong emission by CO, near 2350 cm⁻¹ (4.3 microns) and another by CO, and H₂O near 3700 cm⁻¹ (2.7 microns). This report is devoted to measurements made in these two spectral regions.

A furnace has been designed and built to heat samples composed of H₂O and CO₂ and other gases to temperatures as high as 2000°K. The sample gas is contained in a small platinum cell with sapphire windows, and the temperature of the sample is uniform to approximately - 10 K. Virtually any mixture of N₂O, CO₂, and any gas which does not react with copper tubing can be investigated at any pressure between approvimately 3 and 1500 mm Mg. The measurements have been made with the a of determining the dependence of emission on the temperature, the optical thickness of the emitting gas, the partial pressure of the emitting gases, and the partial pressure of other non-emitting gases which are present. Mitrogen has been used as a non-emitting foreign gas. It is believed that the information presented in this report, along with that which will result from continued investigations, will be invaluable in making calculations of the emission from flames which are larger than can be produced in the laboratory, and are non-uniform in temperature and in composition. The type of information provided by the present investigation is essential for the development of proper band models necessary for such calculations.

Since the objective is to obtain quantitative data on effects of pressure, temperature, etc., it was decided to investigate samples heated by a furnace rether than flames. Much better control of samples contained in a cell heated by a furnace is possible. The temperature and composition can be kept uniform throughout the sample, while these parameters are variable throughout a flame. The temperature, pressure, and composition can also be varied over much wider ranges. Results of the CO₂ and H₂O measurements are presented in Sections 3 and 4, respectively.

A second phase of the study involves the transmission of radiation through synthetic atmospheres. Considerable work has been done on the transmission of radiation from continuous sources, such as glowers and hot filaments, through atmospheric paths. However, the problem is further complicated when the source of radiation is a gas flame containing the same species as the absorbing gas. The complication results from the fact that many of the emission maxima occur at the same frequencies as the absorption maxima. A detailed discussion of this effect is presented in Section 5 along with the results of several measurements which have been made.

Since the investigations are being continued, very little analysis of the data i. presented in this report. The data are presented in considerable detail in the form of tables and figures so that they can be used conveniently by other workers for comparison, or for a basis for theoretical calculations. Further reports on this investigation will contain a considerable amount of analysis; and comparisons will be made with results of related investigations by workers at General Dynamics, Warner and Sugaey, University of California, Israel Institute of Technology, and Armour Research Institute. Effects of temperature, pressure, optical thickness, etc. will be determined and the usefulness of different band models will be considered.

Units, Symbols, and Definitions

The Greek letter v is used to denote the frequency of radiation in wavenumber $(cm^{\frac{1}{4}})$, the number of waves per centimeter in vacuum. Navelengths are measured in microns and denoted by λ . Prequencies in $cm^{\frac{1}{4}}$ can be found by dividing 10^{6} by the vavelength in microns.

k() is the true absorption coefficient at frequency v as it would be observed with an instrument having infinite resolving power. Wherever "true" is used with absorption coefficient, transmittance or

emissivity, it corresponds to infinite resolving power. True transmittance is given by exp(-k(v)u), where u is the optical thickness.

 $T(\nu)$ is the transmittance of a sample measured at frequency ν with a continuous source and a spectrometer having finite slit width. The transmittance of a gas sample is the ratio of the radiation transmitted by the gas to that incident on it. Absorptance is denoted by $A(\nu)$ and is $1-T(\nu)$. Emissivity $\varepsilon(\nu)$ is also $1-T(\nu)$; absorptance is used with reference to cold gases for which the interest is in the absorption of radiation. Emissivity is used with reference to hot gases whose radiation characteristics are being studied. The emissivity of a gas is the ratio of the emitted radiation power to the radiant power from a blackbody at the same temperature. $\overline{\varepsilon}$ is used to denote the average value of $\varepsilon(\nu)$ over a specified interval.

 $N(\nu)$ denotes spectral radiance in watts ster $^{-1}$ cm $^{-2}$ cm $^{-1}$. N denotes radiance in watts ster $^{-1}$ cm $^{-2}$; either for all frequencies or over a specified interval. Different subscripts and superscripts used with the symbols described above refer to specific cases. For example $N^B(\nu)$ denotes the spectral radiance of a blackbody. $T_{C}(\nu)$, $T_{H}(\nu)$ and $T_{HC}(\nu)$ denote transmittances of a cold gas, a hot gas, and a hot and cold gas in series, respectively. When an asterisk is used with a symbol for transmittance such as $T_{C}^{*}(\nu)$, it denotes the transmittance that would be observed with a hot gas source.

Total pressures are denoted by P, and partial pressures of individual gases by $p(CO_2)$, $p(H_2O)$, etc. All pressures are measured in mm Hg.

Values of optical thickness u for ${\rm CO}_2$ samples are determined in atmos on STP by

u (atmos cm STP) =
$$\frac{p(CO_2)}{760}$$
 L $\frac{\theta_0}{\theta}$, (1-1)

where L is the length of the sample in cm, θ is standard temperature, 273 K; and θ is the gas temperature in 6 K. Dividing by 760 converts the pressure to atmospheres. The temperature factor θ / θ is to be noted since many authors do not apply it in their calculations. In the present investigation this factor is used so that a given value of u in gtmos cm STP corresponds to the same value in moles per cm or gms per cm , regardless of the temperature. In the case of CO₂, values of optical thickness can be converted from atmospcm STP to gms per cm by multiplying by 1.96×10^{-3} .

In the case of $\rm H_2O$, values of u are expressed in precipitable on (pr. on), which is numerically equivalent to gas per on, and one calculated by

u (pr ca H₂0) =
$$\frac{P(H_20)}{760}$$
 $\frac{1.90}{6}$ 5.90 x 10⁻⁴ (1-2)

The term optical thickness is used instead of absorber concentration which has been used for the same quantity by some workers, including the cuthors. Optical thickness has been chosen since it seems to be more descriptive; units used in the present report are based on those used most often by other investigators deing similar work.

SECTION 2

EXPERIMENTAL

Apparatus

A diagram of the optical components of the apparatus is shown in Figure 2-1. Radiation from a Hernst glower passes a 13 cps chopper and is fucused near a small absorption cell inside the furnace. The absorption call is not shown in Figure 2-1, but the sapphire windows which fit it are shown. After passing through the cell, the radiation travels on through the furnace and an image of the glower is formed on the slit of a Ferkin-Elmer Model 99 monochromator. The absorptance at any frequency is obtained by comparing the signal observed with a sample in the hot cell to that observed with the cell evacuated. Since the furance is between the chopper and the monochromator, radiation from it is not modulated and is not detected. Absorption by the windows is accounted for by the comparison of the spectra. If one were to use the ho; gas directly as a radiation source, error would arise from radiation emitted by the windows or reflected from them. This radiation could not be very accurately accounted for by comparing the signal with a sample in the cell to that obtained with the cell evacuated. Each window would not only emit and scatter radiation into the instrument; it would also absorb a portion of the radiation from the preceding components. For example, the cell window on the side next to the monochromator would absorb part of the radiation emitted by the gas and by the window on the opposite side of the gas. Similarly, the sample gas would absorb part of the radiation from one window and none from the other. Thus, it is apparent that the contribution of the radiation due to the windows would change with the gas sample and would be very difficult to determine.

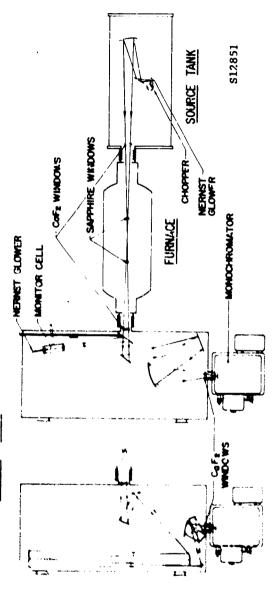


FIGURE 2-1. OPTICAL DIAGRAM OF APPARATUS. RADIATION FROM A NERNST GLOWER IS POCUSED NEAR THE CENTER OF A SAMPLE CELL WHICH IS LOCATED IN THE PURIACE. THE RADIATION PASSES ON THROUGH THE FURNACE AND AN IDAGE OF THE GLOWER IS PORMED ON THE SLIT OF A PERKIN-ELMER PRISM MONOCYROMATOR. THE SAMPLIE IS CONFINED TO THE REGION BETWEEN THEM. ARCON FILLS THE TWO END SECTIONS OF THE FURNACE BETWEEN THE SAPPHIRE AND CAP, WINDOWS. A FLAT MIKROR CAN BE MOVED INTO THE PATH OF THE BRAM LEAVING THE FURNACE SO THAT IT DIRECTS LIGHT FROM A NERNSY GLOWER OMTO THE SLITS OF THE MONOCIROMATOR. THE LEFT-HAND PORTION OF THE PIGURE SHOWS THE OPTICAL ARRANGEMENT USED TO OBTAIN LONG PATH LENGTHS WHEN THE OPTICS TANK WAS USED AS AN ABSORPTION CELL.

•

Since, according to Kirchhoff's Law, the emissivity of a body in thermal equilibrium is equal to its absorptance, the emissivity can be determined from the measurements. The spectral radiance can then be calculated from the product of the emissivity and the spectral radiance of a blackbody at the temperature of the sample.

In order to reduce errors in emissivity measurements arising from absorption by atmospheric gases, all the optical path except for that in the monochromator and the furnace is confined to a source tank and an optics tank. Either tank can be evacuated and filled with gas to any desired pressure less than atmospheric; the optics tank is usually evacuated, while the source tank is evacuated and then filled with dry nitrogen. While making some measurements of the type described in Section 5, absorbing gas is put in the optics tank. The source tank is not operated under vacuum in order to avoid possible trouble with the chopper and because of a tendency of the Nernst glower to evaporate and form a film on the mirrors. The lid of the monochromator is connected to the window at the end of the optics tank by means of a bellows to reduce leakage of air into the region under the lid, which is flushed with dry nitrogen at the rate of about 3 liters per minute. Under these conditions, it is possible to reduce the maximum absorptance in the regions of the CO2 bands at 2350 cm-1 and the H2O bands at $3^{9}00 \text{ cm}^{-1}$ to about 0.01 or 0.02.

The monochromator was originally placed inside the optics tank where it could be evacuated and filled with dry nitrogen, but later it was decided to use it outside the tank, as shown in Figure 2-1, to avoid complications in making slit adjustments and in scanning the Littrow drive.

The optical system for the optics shown in the left-hand portion of Figure 2-1 is used when it is desired to have a rather long path of absorbing gas in "series" with the gas in the furnace. An image of the glower is formed adjacent to the single mirror of a multiple-pass mirror system similar to that described by White. In the studies using this system, which are described in Section 5, the number of passes could be varied from outside the tank without opening it or without changing the gas in it. The maximum number of passes used was 24, which correspon's to a total path of more than 2600 cm within the optics tank.

The image of the glower formed near the hot sell is enlarged by a factor of a proximately three. This image is then reduced by about the same factor, giving an image approximately 0.4 cm high on the slit of the monochromator. By decreasing the f-ratio in this manner,

the beam entering the monochromator "fills" more than 80 percent of the prism. Since there is some vignetting, and since the height of the slits is about 1 cm compared to the image height of 0.4 cm, the monochromator is only about 30 percent filled. In an optical system such as this, the maximum resolving power is limited by the minimum slit width compatible with the desired signal-to-noise ratio. The resolving power is approximately proportional to the reciprocal of the physical slit width, and the signal is nearly proportional to the square of slit width. Thus, the maximum resolving power is about one-half as great as if the monochromator were completely filled. Since high resolving power is not essential in the present study, the factor of two which is lost is not considered important.

It would be possible to more nearly 1:11 the monochromator optics by using an image-splitter or by increasing the aperture of the furnace; but the advantages that would be realized do not appear to justify the inconvenience. If the aperture of the furnace were increased by enlarging the opening, more power would be required and it would be much more difficult to maintain uniform temperature over as long a portion of the furnace. An image-splitter which would split an image of the glower vertically into two halves and re-image them, one above the other, could make use of more of the height of the slit. Such a device takes advantage of the fact that the image formed on the slits is usually much wider than the slit opening; some of the radiation that would ordinarily be wasted is then used to form a higher image without increasing the f-ratio of the beam. However, in view of the fact that the optical system is already complex, the further complication of an image-splitter did not seem justified.

In the normal operation of a Perkin-Elmer double-pass-monochromator, the beam is chopped internally after one pass at a point conjugate to the exit slit. For any setting of the Littrow mirror, there is some frequency which passes through the exit slit after only a single pass (actually two passes through the prism, since the beam traverses the prism twice in a single pass instrument and four times in a double pass), but the single pass radiation is not detected because it has not been chopped. However, if the beam is chopped externally, as in the present study, sime modifications must be made in order to avoid simultaneous detection of radiction at two different frequencies, one single passed and one double passed. To double pass the instrument while using the external chopper, the bottom halves of the entrance and exit slits were blocked off. The single-pass radiation from the top half of the entrance slit is focused on the bottom of the exit slit which is blocked off. Single-pass radiation is therefore not detected. During the second pass, the image of the entrance slit is reinverted so that the dr. ble-pass radiation

entering the upper half of the entrance slit passes through the upper half of the exit slit. Since the height of the image of the Nernst glower formed at the entrance slits is less than half the height of the slits, no loss in signal was introduced by blocking half of each alit.

The instrument was double passed to take advantage of the increased dispersion. Also the frequency calibration and the dispersion are the same as when the instrument was double passed while using the internal chopper in conjunction with other optical systems, such as the Nernst glower and monitor cell in the optics tank. When using the external chopper the internal chopper is positioned so that it is out of the beam. A window has leen added to the lid of the monochromator so that the internal chopper can be viewed while positioning it.

With the monochromator double passed in this manner, the "scattered light" was less than 0.1 percent of the total radiation near the 3700 cm $^{-1}$ region and was about 0.5 percent in the region of the strong CO₂ absorption near 2350 cm $^{-1}$. The amount of scattered light was determined by comparing the recorder deflection with the entrance slits covered to that with a sample of CO₂ large enough to produce complete absorption. Since the amount of scattered light was so small, it could be accounted for sufficiently well to avoid significant error.

If the physical slit width of the monochromator were kept constant while scanning over the entire region of CO2 absorption near 2350 cm⁻¹, the recorder deflection on the low frequency side was found to be only about 20 percent as great as that on the high frequency side. In order to reduce the change in deflection from one side of the absorption region to the other, the slit servomechanism built for the monochromator by Perkin-Simer was used to open the slits automatically according to a pre-determined program. A nonlinear electrical cam which was custom made in our laboratory was found to produce a reasonably smooth background when used with the Perkin-Elmer slit servo. The physical slit width was kept constant while ecanning the region near 3700 cm⁻¹ since the change in recorder deflection from one side of the region of absorption to the other side was less than for the region near 2350 cm-1. A further reason for using constant slits at higher frequencies is that the slits are narrower and a smell error in the servo mechanism would produce a larger error in the recorded signal.

Table 2-1 gives values of spectral slit width $\Delta \mathcal{V}$ at several frequencies for the different slit programs used. The values are based on curves in the instrument instruction manual relating $\Delta \mathcal{V}$ to the physical slit width, and are one-half the width of the total spectral interval passed by the slits. These values are approximately the same as would be obtained by using the Rayleigh criterion. In the discussion of the results, reference is made to the resolution schedule which was used while obtaining the data.

TABLE 2-1
RESOLUTION SCHEDULES

Wavenumber		(AV) 1	n cm - 1		
	Δ	B	<u>ç</u>	<u>D</u>	
1800	3.7	5.0			
2000	3.5	4.8			
2200	3.2	4.6			
2400	3.1	4.4			
2600		4.6			
2800			2.9	4.2	
3000			3.5	5.2	
3200			4.3	6.4	
3400			5.1	7.6	
3600			6.0	8.9	
3800			7.0	10.4	
4000			8.1	12.0	
4200			9.2	13.7	
4400			10.4	15.5	

The synchronous motors, which drive the recorder chart and the monochromator Littrow drive, were replaced by selsyns. Both of these selsyns are now driven from the same transmitter which is powered by a variable speed d.c. motor. With this arrangement the recorder chart and Littrow drive are synchronized so that the frequency calibration on a spectrum remains the same and the scanning speed can be varied. The scanning speed is manually controlled so that there is sufficient time for the recorder to respond and give a true reading. Portions of the spectrum with little or no structure can be scanned as much as 5 times faster than the portions containing considerable structure. By varying the speed the scanning time is reduced to about 60 or 70% of the time required for a constant scanning speed which is decemined by the region having the most structure.

A gas handling system, which is described in considerable detail in Appendix B, was designed to deliver gas samples to the sample cell in the furnace at any desired pressure between approximately 3 and 1500 mm Hg. Virtually any gas mixture, including water vapor, which will not react with copper tubing can be produced and flowed continuously through the sample cell at a regulated pressure. All the components which contain sample gas can be heated to approximately 140°C in order that H_aO can be investigated without condensation in the lines. Argon which is Inactive in the infrared is continuously flushed through the section of the furnace arould the sample cell. The argon pressure is maintained very close to that of the sample in order to avoid rupturing the thin sapphire windows of the sample cell and to reduce leakage past them. The windows are only 0.5 mm thick so that absorption of radiation by them is kept to a minimum. Absorption by sapphire becomes important at high temperature at frequencies below about 2200 cm $(\lambda > 4.5u)$.

Both the sample gas and the argon are fluened continuously to avoid accumulation of either of these gases in the wrong section of the furnace, and to carry away any impurities that might arise from slow reactions or from de-gassing from the walls of the furnace, which might occur because of the high temperatures. A small absorption cell and a separate radiation glower were employed in order to monitor the composition of the gases by observing their absorption spectra. The arrangement is shown in Figure 2-1. A small flat mirror located inside the optics tank can be moved into the path of the beam coming from the furnace, thus blocking it from the monochromator. When in this position, the mirror directs light from a Nernst glower onto the monochromator. Located in the beam is a small absorption cell, labeled as a monitor cell, which is connected to the gas handling system. The primary purpose of the monitor cell is to contain samples of gas which can be bled

from either the hot call in the furnace or from the argon sections. Spectra of these samples can be obtained periodically to monitor the composition of these gases. For example, the purity of the argon is monitored to check for possible leakage of excessive amounts of sample gas into the argon section. By comparing the spectra with others obtained for known mixtures in the cell, it is possible to estimate the amount of sample gas present. On the basis of checks made while obtaining the data presented in this report, it was found that there was usually less than 0.05 of one percent sample gas in the argon. Error arising from the presence of this gas is therefore small. Similar checks of gases bled from the hot cell indicated that the deviation from purity was usually less than could be detected. The purity was therefore believed to be great. Than 98%. While obtaining spectra of samples in the monitor cell, the internal chopper was used.

Because of condensation in the cold lines, water vapor from the hot cell could not be bled into the monitor cell. However, the same handling procedures and flow rates were used for water vapor as for CO2 and it was assumed that negligible error was introduced by leakage.

Recording of Data

Before and after the spectra of a series of samples were obtained, background spectra were run with the sample cell evacuated but with all other experimental conditions the same as those for the samples. The frequency interval covered by the background spectra was somewhat wider than that over which the largest sample would absorb. In the case of $\rm CO_2$ samples—the region near 2350 cm⁻¹ and the one near 3700 cm⁻¹ were scanned separately. When studying $\rm M_{2}O$, the region near 3700 cm⁻¹ was scanned in one continuous spectrum.

Samples were usually divided into sets composed of a given mixing ratio at different pressures. In general, the first sample was at the lowest pressure at which the absorption was sufficiently great to be measured with reasonable accuracy. Succeeding samples were at higher pressures, where the pressures were increased by a factor of approximately two between samples. After the sample pressure was changed, but before a spectrum was scanned, the flow rates of the sample gas and argon were adjusted to some predetermined optimum value and the flow was maintained for a few minutes. Immediately after each spectrum was scanned the recorder deflection was checked at a few key frequencies within the band. If the deflections at these frequencies were the same as were observed during the scan, it was assumed that

there was a negligible drift. In cases of excessive drift the spectrum was re-run.

Reduction and Presentation of Data

Curves which represent recorder deflection for no sample absorption were superimposed on each sample spectrum by tracing the appropriate background spectrum. There were always at least two background spectra for each sample, one obtained before the sample spectrum and one after it. Comparison of the different backgrounds provided a check for drifts within any one spectrum and for other possible "long term" variations which might occur between the times they were obtained.

There is, of course, some uncertainty in fitting a beckground to a sample spectrum. This uncertainty is particularly noticeable in the wings of a band if the absorptance decreases very slowly. The error which might arise in any individual spectrum can be reduced by "nesting" all the curves belonging to a set of samples. For example, if samples of a given mixing ratio at 9 different pressures were studied, the spectra of several of these samples can be superimposed. Since it is known that the absorption at any frequency increases with increasing pressure, the absorption indicated by any single sample should be consistent with that of the other samples. Better accuracy can be attained by this technique, since information from several spectra is used to determine the spectrum of any single sample.

After the backgrounds have blen drawn the information is put in digital form for use on an IM 7090. Values of recorder deflection are recorded on punched cards for enough points to define the curve; the points at which any curve is read are chosen according to the amount of structure and occur at variable density along the curve. As an approximate criterion, points are read at every maximum and minimum and at points in between so that straight lines joining them will not deviate from the curve by an amount corresponding to more than 1/4 percent transmittance. The same criterion is used for the background curve as for the sample curve, and no attempt is made to read both curves at the same frequencies. Each card contains information about the recorder deflection and about the x-value, from which the frequency is calculated. A program for the IBM 7090 has been developed to provide the following output for each sample whose emission is being studied.

(1) Values of emissivity € (T) = 1 - T(T), and frequency in cm⁻¹ at all points where the sample spectrum was read.

- (2) Values of N(v) st the same frequencies; N(v) is the spectral radiance of the gas computed from the product of ∈(v) and the spectral radiance of a blackbody at the temperature of the gas.
- (3) Values of ε, the average emissivity over 5 cm⁻¹ intervals. These are determined by averaging values of ε(ν) which are calculated at integral wave numbers as an intermediate step.
- (4) Values of N the radiance in watts cm⁻² ster⁻¹ for the 5 cm⁻¹ intervals. These values are determined from the product of 2 for the same interval and 5N^B(v), where N^B(v) is the spectral radiance it the center of the interval of a blackbody at the same temperature as the gas. Since the spectral radiance of a blackbody is nearly constant over a 5 cm⁻¹ interval for the temperatures and frequencies covered in the present study, the simple product is a very good approximation to the radiance of the interval.
- (5) Values of \$\vec{e}\$ for 50 cm⁻¹ intervals, determined by one-tenth the sum of the values of \$\vec{e}\$ for the ten 5 cm⁻¹ intervals
- (6) Values of N for 50 cm⁻¹ intervals, determined from the sum of the values for the ran 5 cm⁻¹ intervals.

In information contained in (1) and (2) are included in the computer output in tabular form and on cards which can be used with an automatic plotter, while the information in (3), (4), (5), and (6) is presented in tabular form only. The curves of emissivity shown in Sections 3 and 4 were plotted from the punched cards, but the remainder of the output described in (1) and (2) above is not included in this report. The emissivity curves are presented rather than photographs of the original spectra which have a nonlinear wave number scale and for which the background curve corresponding to 100% transmittence is not constant. Tabular information from (3), (4), (5) and (6) above is presented in Sections 3 and 4.

The results of the investigation of the transmission of radiation from not CO, through cold CO, are presented in a different manner in Section 5 slong with a discussion of experimental techniques, data, and the theory involved. The major portion of the results obtained are presented in this report in a manner that should be convenient for workers who need the raw data to compare with their results or for others who are interested in fitting data to various band models. Very little analysis is presented here since more data will be obtained in the near future and a detailed analysis of all the data will be performed at that time.

Errors and Accuracy

In a study such as this there are certain sources of error which arise from sampling, from data recording, and from data analysis. Uncertainties in sampling are somewhat larger in the present study than in studies that are not complicated by the high temperatures and by the necessity of flowing the sample continuously while making measurements. The recorded temperature of the sample of hot gas is accurate to approximately $\frac{1}{2}$ 100K; this uncertainty causes approximately $\frac{1}{2}$ 1% error in the calculation of optical thickness, which is inversely proportional to temperature at a given pressure.

Approximately 1 % error in the calculation of optical thickness arises from the uncertainty in the length of the sample cell at high temperatures. Available data on the coefficient of thermal expansion of the cell material only covers temperatures to 1000°C. The cell length at the higher temperatures was calculated by assuming the same coefficient of expansion as for the lower temperatures, and the value calculated for 1500°X is used for all temperatures above 900°K since the change in length at the different temperatures is very small.

On the high frequency side of the CO₂ bands an increase in temperature, at constant pressure, results in a decrease in emissivity, while on the low frequency side an increase in temperature causes an increase in emissivity. Under most conditions and at most frequencies, a 1 percent error in temperature would probably cause less than 1 percent error in the measured value of emissivity, but on the extreme low frequency side the error in emissivity might be as large as 3 or 4 percent.

Further sampling error arises from impurities and from uncertainties in the mixing ratior of the gases. $\rm H_2O$ is the only impurity in the $\rm CO_2$ and $\rm CO_2$ + $\rm N_2$ mixtures which absorbe infrared radiation in the regions of the $\rm CO_2$ bands, but even the absorption by $\rm H_2O$ near 3700 cm⁻¹ is very small for hot samples and can be accounted for without introducing significant error. The $\rm CO_2$ + $\rm N_2$ mixtures were obtained from a local gas supply company which claimed an accuracy

of $\frac{1}{2}$ 0.5 percent. Unfortunately, many of the emissivity measurements were made before it was discovered that the mixing ratios of the gases did not meet the specifications. The gases ordered were supposed to be 1/16, 1/8, and 1/2 CO₂, but were found to have the mixing ratios of 0.074, 0.145 and 0.53, respectively. The values were determined by carefully comparing the infrared absorption by the pre-mixed samples to that by samples mixed in the laboratory. Measurements were made with an absorption cell at room temperature. Repeated measurements made by using different mixing techniques indicated that the fractions of CO₂ quoted above are accurate to approximately $\frac{1}{2}$ 1 percent except for the most dilute mixture which may be in error by as much as $\frac{1}{2}$ 2 percent. The purity of the "pure" CO₂ and of the H₂O investigated was probably greater than 99 percent.

Further uncertainty in sampling 's introduced by the small leakage past the windows of the cell. The small amount of sample gas present in the end sections of the furnace tends to give an emissivity reading which is too high, while the argon which has leaked into the sample cell tends to make the reading too low. It was found that the emissivity measurement was insensitive to change in sample and argon flow rates over a wide range, indicating that the flow was not too fast for the gas to heat to the proper temperature and yet it was sufficiently fast to provide flushing. As a result of these findings, along with the spectra obtained for the gases bled into the monitor cell, it was concluded that leakage could not give rise to more than I l percent uncertainty in the measured values of emissivity.

Absorption by the small amount of $\rm CO_2$ and $\rm H_2O$ which could not be flushed from the monochromator could give rise to a maximum error in emissivity of approximately 0.01 at the frequencies of maximum absorption in the background. The absorptance by the residual $\rm CO_2$ and $\rm H_2O$ was greater than 0.02 or 0.03 in only a few cases. This absorption can be partially accounted for, so that the maximum error should not exceed that stated above.

Certain small errors are introduced by possible nonlinearity of the detector and amplifier and by scanning too fast for the recorder to respond completely to give an accurate reading. According to the instrument manufacturer's specifications, the maximum error in emissivity values caused by nonlinearity of the detector and amplifier should not exceed 0.005 for values of emissivity near 0.50 and should be even less for values nearer zero or unity. Error introduced by scanning too fast for the response of the amplifier should be negligible, except possibly for frequencies near a very steep slope on the spectrum,

such as occurs on the high frequency side of the CO₂ absorption in the 2350 cm⁻¹ region. Haxima and minima on the recordings may tend to be slightly "rounded" and shifted toward the direction of scan, which in the present study is from high to low frequencies. Since considerable care was taken to determine the proper scanning speads, which were varied from one portion of a spectrum to another, the maximum error in emissivity due to slow "dynamic response" should not exceed 0.01 at any frequency, and the average over a 5 cm⁻¹ interval is considerably less.

The operator of the digital read-out machine can read the recordings with an uncertainty that corresponds to approximately 2 0.004 in emissivity. The machine program performs the calculations as if the curves were composed of straight lines between the points read, and the points were sufficiently close that this "assumption" should never produce errors greater than 0.001 in the calculated values of average emissivity for 5 cm⁻¹ intervals which are tabulated in Sections 2 and 3. Any other errors due to the machine are negligible, except for mistakes in the input such as duplicate cards or cards which were punched wrongly. Output errors due to incorrect cards are usually obvious when the emissivity curves are plotted, and corrections can easily be made. However, it is possible that a few obscure errors still exist in the tables of Sections 3 and 4. If so, these errors would appear in a close comparison of the tables with emissivity curves.

Errors in the frequency calibration of the spectrometer, which are approximately $\frac{1}{2}$ 1 cm $^{-1}$ near the 2350 cm $^{-1}$ region and $\frac{1}{2}$ 2 cm $^{-1}$ near 3700 cm $^{-1}$, tend to shift the spectra but do not change the structure. Of course, such errors in calibration can produce large errors in emissivity at a particular frequency measured on a steep slope of a spectrum, but the error introduced for a very wide interval or band is negligible.

Because of the many sources of errors and because some are important for some conditions and not for others, it is difficult to numerize the uncertainties of the results in a concise manner. But, for most cases, it is believed that the values of emissivity less than 0.10 are probably accurate to 2 0.01, while the uncertainty may be as large as 2 0.03 or 0.04 for values of emissivity greater than approximately 0.5. It should be noted that <u>differences</u> in emissivity between neighboring frequencies, which are much less than the stated values of uncertainty, can be detected. This is true because the occuracy of the "shape" of a spectrum is considerably better than the absolute occuracy of the measurement at a single frequency. Changes in emissivity as small as 0.001 or 0.002 can frequently be detected between neighboring points.

SECTION 3

RESULTS: EMISSION BY HOT CO,

This section contains the results of emission data obtained for more than 60 samples of CO, and CO, + N, at 1200°K and 1500°K. Mixtures of CO, + N, containing 7.4%, 14.5%, 53% and 100% of CO2 were investigated at total pressures between approximately 6 and 1500 mm Hg. The lungth of the sample cell was 7.75 cm at the high temperatures. In general, the spectra were obtained in sets consisting of samples having a fixed temperature and fixed mixing ratio but at different total pressures. For a given sample the spectra of the 2350 cm and the 3700 cm regions were recorded separately. Several of the samples at lower pressures did not produce significant emission in the 3700 cm region, and spectra were not scanned in this region. Although spectra were obtained in both regions for many of the samples, each spectrum has been given a different sample number for reference. Sample numbers for the 2350 cm region are prefixed by the letter F, while those for the 3700 cm.

Figures 3-1 through 3-8 show curves relating emissivity to frequency for the F-samples. The curves were replotted from the spectra obtained with spectral resolution given by schedule A in Table 2-1. Since loss of a little structure in the process of replotting is inevitable, all the emissivity curves shown in this report probably correspond to a spectral slit width 1 or 2 cm⁻¹ wider than that shown in the corresponding resolution sheedule.

Emissivity curves for the T spectra (3700 cm⁻¹) region are shown in Figures 3-9 through 3-14. Resolution schedule C (Table 2-1) applies to the spectra from which these curves were obtained.

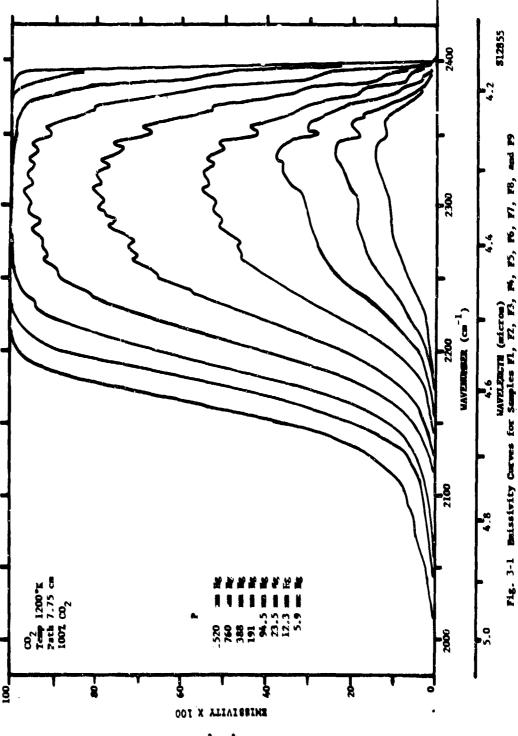
The growth of the emission with increasing pressure is seen to be quite large. It is well known from similar studies of absorption by gases at lower temperatures that the growth observed by increasing the pressure of a given mixture is a result of both the increase in optical thickness and the increase in line width associated with higher pressure.

Ų.

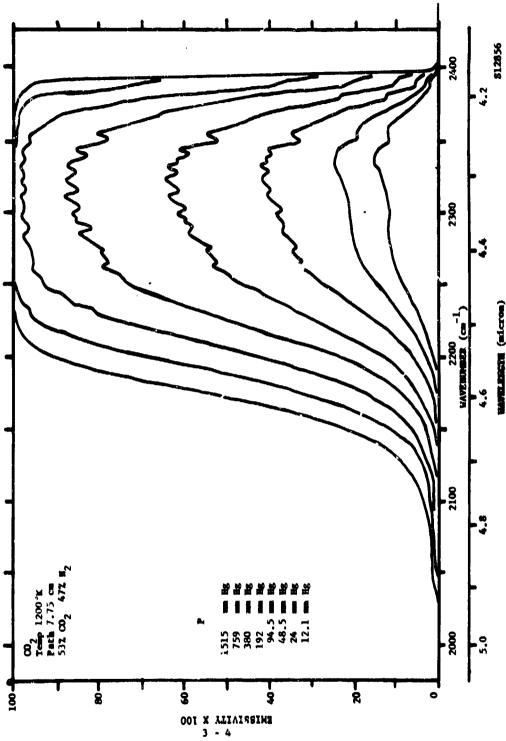
In Figure 3-15 are shown a set of curves relating $\int e(v) dv$ over the 2350 cm. region to total pressure for four different gas mixtures at 1200°K. The quantity $\int e(v) dv$ corresponds to the quantity $\int A(v) dv$ which is frequently used in absorption studies of gases because it is independent of the slit function under usual experimental conditions, provided the integration is carried out over the entire region of absorption. The features of the curves of Figure 3-15, which are drawn on log-log scales, are quite similar to curve, of $\int A(v) dv$ for samples at room temperature which have been published. The curves contain an almost straight portion and tend to level off at higher pressures as the emissivity approaches a maximum value of unity over much of the region, and the only growth occurs in the wings of the emitting region.

In order to demonstrate the effect of increasing pressure while maintaining constant optical thic ness, points were read from the curves of Figure 3-15 and plotted in Figure 3-16, where such curve corresponds to a constant value of optical thickness. A rather small dependence on pressure is observed; the maximum slope of any of the curves is approximately 0.2, which indicates that the maximum dependence on pressure is $P^{0.2}$. It should be noted that the total pressure used in the abscissa of Figure 3-16 is due to $CO_2 + N_2$; and different points used in obtaining the curves represent samples having different ratios of the two gases. No attempt has been made to account for the different broadening abilities of the gases to obtain an equivalent pressure which is directly related to the widths of the spectral lines. The necessity of accounting for the different broadening abilities has been explained in considerable detail by Burch, Singleton, and Williams . The curves of Figure 3-16 illustrate the effect of pressure broadening by an inert gas, N_2 ; but the dependence of emissivity on line width cannot be determined until measurements of the different broadening abilities have been made. Such measurements are planned in the near future as a part of the present investigation.

Information about each sample and about the measurements are given in considerable detail in Tables 3-1 and 3-2, covering the 2350 cm and 3700 cm regions, respectively. The tables were compiled by "stripping in" the output from the IBM computer for each sample; the tables were then photographed and reduced to page size.



3 - 3



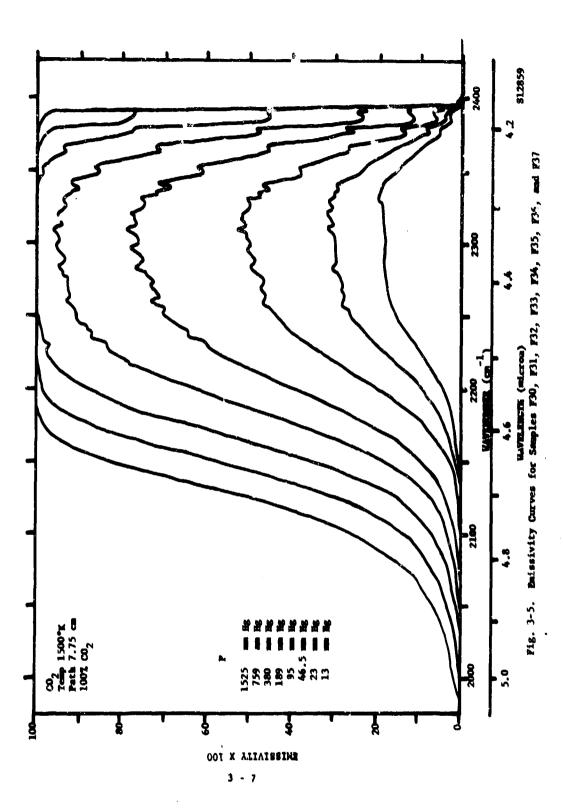
WANTERSTH (aderon) Fig. 3-2. Baissivity Curves for Samples FIO, FII, FI2, FI3, FI4, FI5, FI6, and FI7

Fig. 3-2. Baissivity Curves for Samples F10, F11, F12, F13, F14, F15, F16, and F17

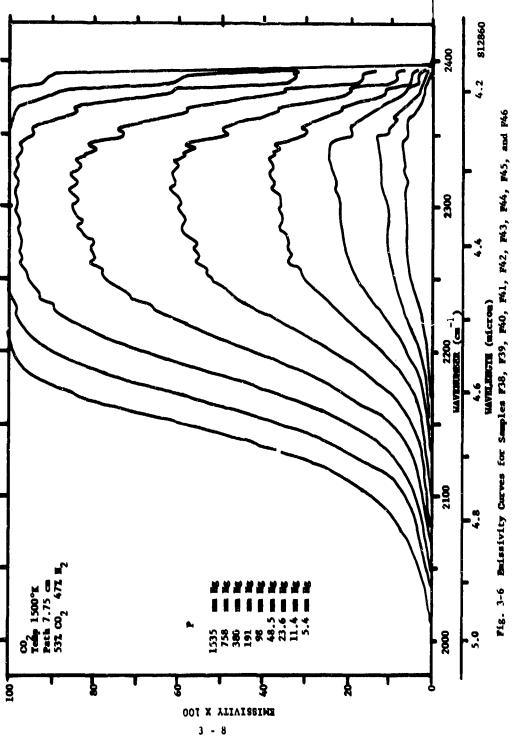
].

7-

Fig. 5-4. Inissivity Couves for Samples FZA, FZS, FZ6, FZ7, FZ8, and FZ9

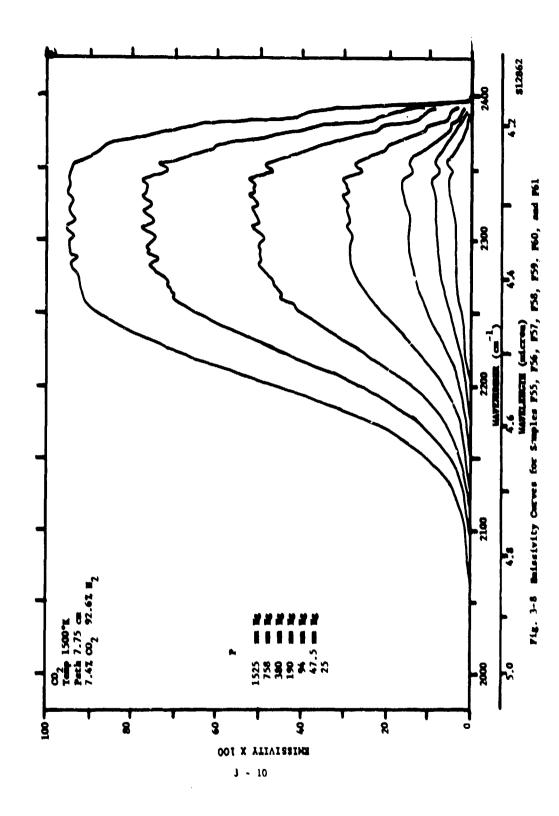


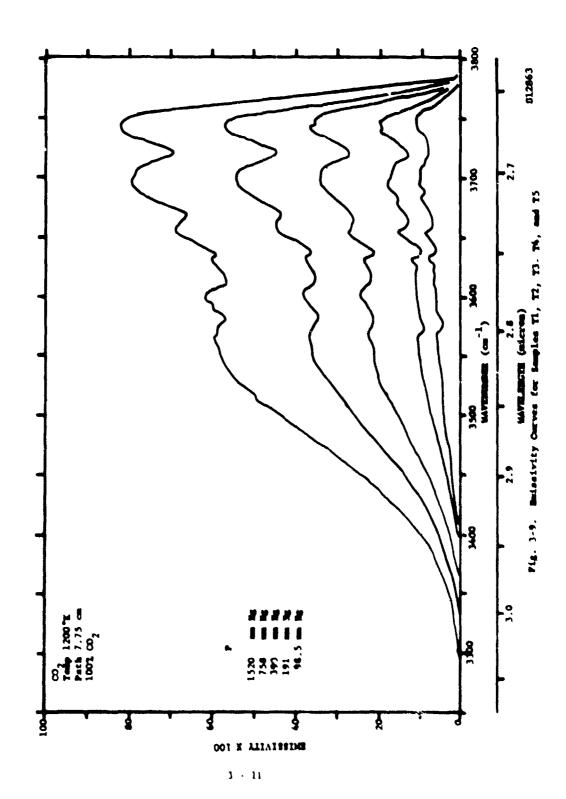
MANAGERIA (MCCTOR)
Fig. 3-5. Emissivity Curves for Samples F30, F31, F32, F33, F34, F35, F36, and F37

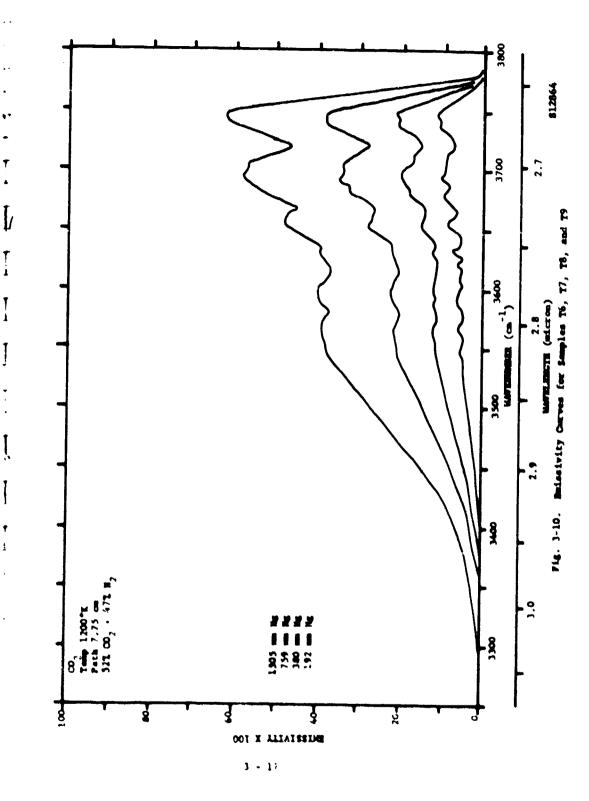


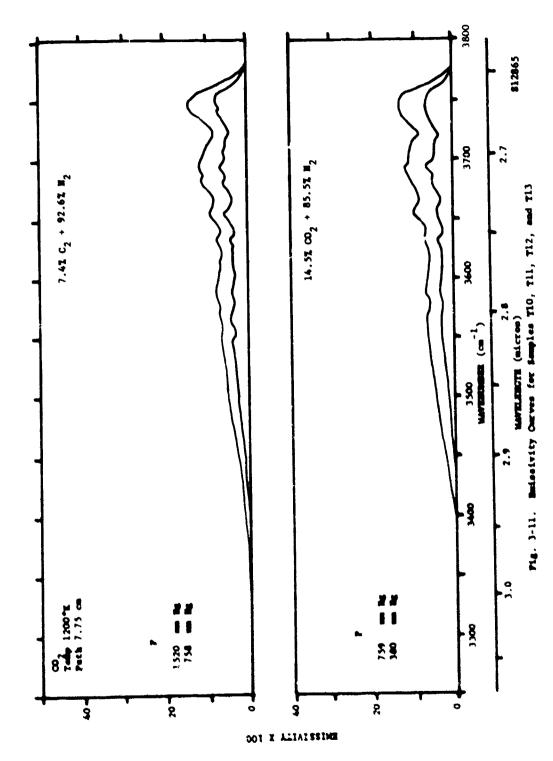
18. 3-6 Estatly Curves for Samples #38, #39, #40, F41, F42, FM3, F44, FM5, and F46

nestvity curves for Suples 167, 168, 169, 150, 151, 152, 153, and 154



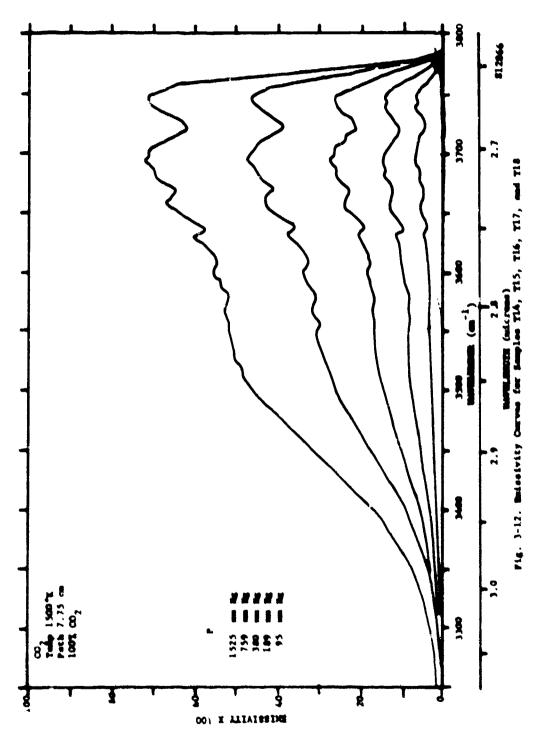


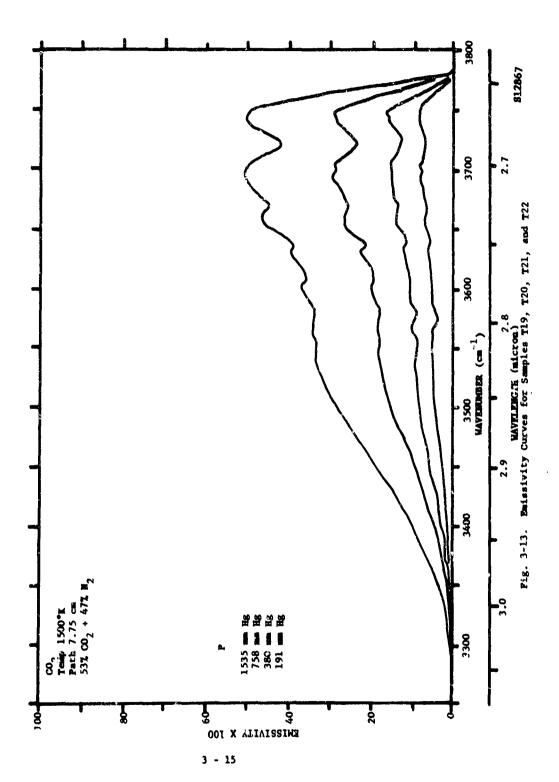




i •

3 - 13





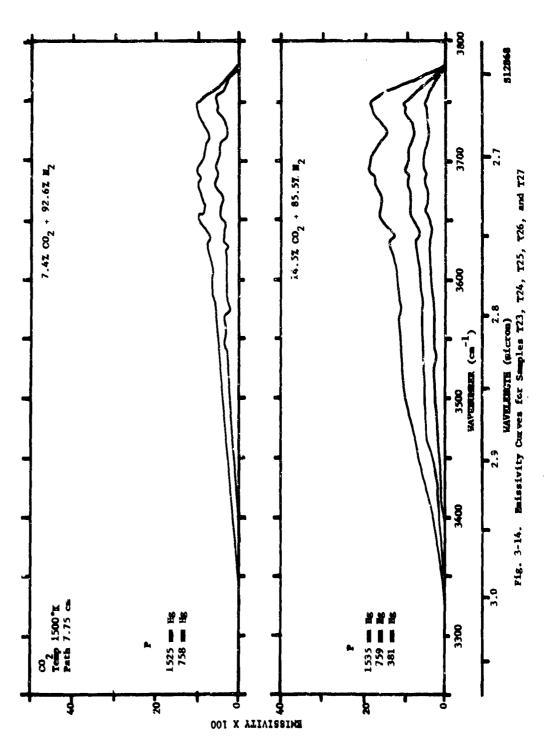


Fig. 3-14. Baissivity Curves for Samples 123, 176, 175, 726, and 727

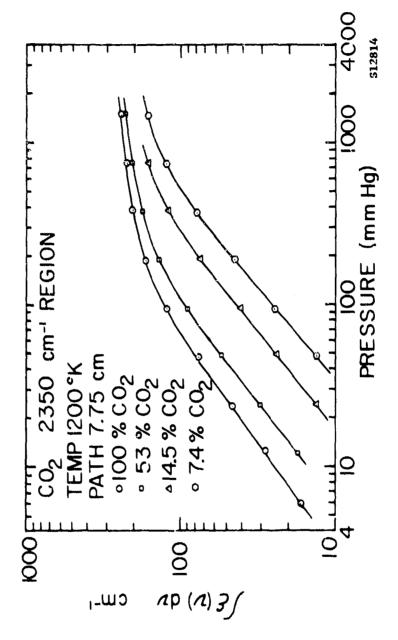


FIGURE 3-15. $\int e(v) dv$ for the 2350 cm⁻¹ region versus the total pressure for saffles baying constant mixing ratio

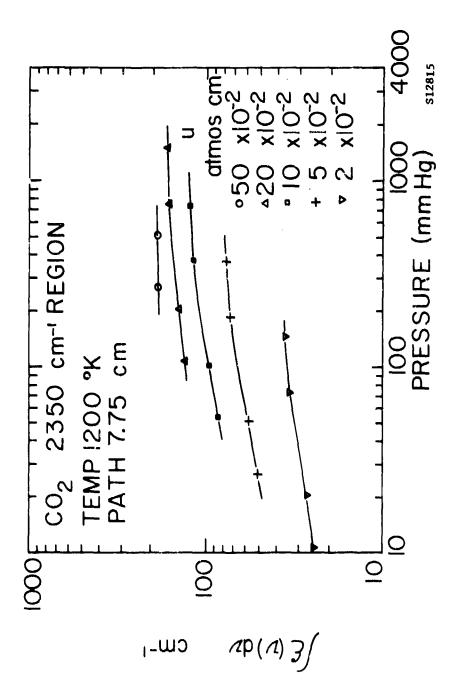


FIGURE 3-16. $\int e(\nu) d\nu$ For the 2350 cm⁻¹ recton versus the total pressure for samples having constant values of optical thickness

INFORMATION FOR USAGE OF TABLES 3-1 AND 3-2

Tables 3-1 and 3-2 have been divided into portions 3-1A, 3-1B, etc., since the information for all the samples included in each table could not be put on a single page. For example, 3-1A covers samples F1 through F7; 3-1B covers F8 through F14, etc. Tables 3-1A, 3-1B, etc. are each on one page, while 3-2A, 3-2B, and 3-2C are each two pages long.

The following information regarding each sample is given at the top of each table: The number assigned to each eample, the temperature, total pressure, ratio of the partial pressure of CO, to the total pressure, the optical thickness u, in atmos cm STP, $\int_{\mathcal{C}} (v) dv$ over the entire region of absorption, and the number of the figure containing the emissivity curve.

The interval is given in cm⁻¹ in the first column and in microns in the second column. The third and fourth columns apply to sample Fl, the fifth and sixth to F2, etc. In the left-hand column under each sample is given T, the average value of emissivity over the interval; the right-hand column under each sample gives the radiance N over the interval in watts cm⁻¹ steradian⁻¹. The multiplication factors 100 and 10,000 at the top of the columns should be noted.

The first portion of each table is devoted to intervals 50 cm $^{-1}$ wide; and the remainder is for intervals 5 cm $^{-1}$ wide. Radiance values for each 5 cm $^{-1}$ interval are found by multiplying 5 times the average emissivity over the interval by $N^{\rm B}(\nu)$, the spectral radiance at the center of the interval of a blackbody at the temperature of the gas. $N^{\rm B}(\nu)$, the spectral radiance of a blackbody at frequency $\nu({\rm cm}^{-1})$ at temperature 0 is given by:

$$N^{B}(v) = 1.1906 \times 10^{-12} v^{3} \left\{ exp \left[1.43868 \frac{\vec{v}}{9} \right] - 1 \right\}$$
 (3-1)

The power radiated from a l cm surface of the gas sample in the fraquency interval involved, through a small solid angle ω in a direction perpendicular to the surface, is given by ωN . The requirement for the power to equal ωN is that the cosine of the angle between the surface and any of the rays in the beam be approximately equal to unity.

The total power radiated in a hemisphere from a 1 cm 2 flat surface of a blackbody is given by $\pi N^B(\gamma)$.

Values of N for the 50 cm $^{-1}$ intervals were found by summing the values for the ten 5 cm $^{-1}$ intervals included; values of $\overline{\epsilon}$ for 50 cm $^{-1}$ intervals were found by taking one-tenth the sum of the values of $\overline{\epsilon}$ for the ten 5 cm $^{-1}$ intervals.

Although the output of the computer included two figures after the decimal point in the $\overline{\epsilon}$ columns and three figures after the decimal point in the N column, the last figure in each of the columns should not be considered significant. Uncertainties in the tabulated values are discussed in Section 2.

TABLE 3-IA														
Somple PL. Tomp. [PM] P form Hg] p [OG] / P u factor om a T.P. Francisco form	1400 Mg 1400 Mg 100 Mg 11 8 a 1 16 8 1-1	1g - 4	74 1400 % 18. 1 1646, 89. 6 4 87. 9	10'1	# 3 #99"1 #3. 6 169% 64. 9 4 #6. 1		74 1340 ° b 47 3 1866 111 11 76 0 1-1		1400" 04 1 100% 441 0 144 1-1		76 1090* 191 160% 647 v 167	H 18 ¹¹	P7 1206" 153 100% 906 u 286 1-1	M 18 ⁻³
im -1 mistans	# 10A	N a 10. 040	8 4 186	N s 18 800	3 a	N &	3.4 .*	N 4 10. 660	24	N a In. 666	44	H 4 19,000	₹ a 100	H u 19, 000
1960-2000 0,1303-0,0000 2000-2000 0,0000-0,2700 2000-2100 0,0000-0,7013 2100-2000 0,0010-0,0010 2100-2000 0,0010-0,000	1	i	8: 6: 8: 8:	i: i:	1:	1111			1					0.070 0.070 110.070
			113	14.747 08.744 185.488 17.818	11,01 21,00 10,00 10,00	11:11					91.61 91.61 96.61		00.10 10,03 15,01 17.10	111:111
1020-2030	1	****	• 0 . • 0 . • 0 .	*****		****	· · · · · · · · · · · · · · · · · · ·		- 0 . - 0 . - 0 . - 0 .	****		4.	in	0. 0. 0. 0.013
	: 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0	1	1	1		Ì	***	****			****			
	#	-#: -#: -#:		1: 1: 1: 1: 1: 1: 1: 1: 1: 1: 1: 1: 1: 1	• • • • • • • • • • • • • • • • • • •	-6, -6, -6,	-0. -0. -0.	1.			*****		1,85 1,85 1,85 1,85	0,116 0,116 0,416 4,744 4,744
	-B. -B. -B. -B.				1		****	****		-6; -6; -6; -4; -4;				1111
#134-8136 x,1944-4,6446 #136-8144 x,046-4,6416 #136-8144 x,046-4,6436 #146-8144 x,046-4,668 #146-8144 x,048-4,668 #146-8144 x,068-4,4418				- 0; - 0; - 0; - 0; - 0;		1		9. 9.010 9.101	1:11	6, 667 6, 667 6, 661 6, 736 1, 855	333	0.00g 1.09j 1.01g 1.01g	1.08 1.07 6.01 6.10 10.07	
	i:	im		0. 0. 0.000 0.114			1:3	8:557 8:557 8:10 1:10 1:10	1:7		111		14.41	
			1.4	6.644 6.44 6.64 6.647 1.166	1:40 1:41 1:41	6,461 1,160 1,610 1,660 6,810		1:010	11.41 14.41 14.41 14.41	9.154 1.641 4.516		8.655 18.667 13.665 13.665 16.665	10.14 17.17 10.17 10.17	
	131				1.10 1.11 11.10					16:111			11:01	11.004 40.004 40.004 40.004
distriction of the second of t	104 104 105 105 105 105		1,10	1.104 1.103 1.110 1.110 1.110			11:11	11.11			### ###		5.7	
	133	1.10	18.47 16.79 16.61 16.67			11,747 14,47 14,47 11,749						11.411 11.114 11.114 11.114	94, 14 94, 11 94, 61 14, 74	
CONTROL CONTRO			11.11			19.93* 19.56* 19.51* 19.64*	######################################	10:100 10:100 10:100 10:100	19.50 19.31 19.31 11.15 19.19		91.11 87.64 87.15 70.16 81.11		******	11.61 11.61 11.61
\$100-2809			14.00 14.14 14.14 11.14	10.100	11.07 11.07 11.07 14.77		11.11 11.11 11.11 11.11		77.48 74.44 94.44 14.55 14.55	10.000 12.001 ke.pp1 00.001	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	7.10 7.11 7.11	100 00 100 00 100 00 100 00 100 00	
145-914	79 61 14:44 14:44 14:44 14:44	1:11		11 554 11 554 11 644 11 644	10, 17 10, 17 11, 17 11, 11	19, 100	31.0	11.20		10 110 10.150 10.150 10.151 10.111	H.01 H.01 H.01 H.01	11.11. 11.11.	H. H. H. H. H. H. H. S.	10.001 11.600 16.601 16.601
			1 1	100		11.164			\$0.04 00.11 10.13 11.00 11.00	11 919 19:41 11 819 11:11 11:81	10.34 10.34 10.34 10.34	11.105 11.105 11.11 11.11 10.15	#.# #:#	16.160 16.111 17.115 18.65 18.65
			1 64 14 16 15			1.00	M / / / / / / / / / / / / / / / / / / /	1. 1 m 1. 1 m 1. 1 m 1. 1 m	24 - 24 24 - 44 18 - 84 16 - 84	11.1M 11.1M 1.0M 1.0M 1.0M		1000	#1.#6 #1.#1 #1.#2 #1.#4	10.111 11.100 10.100 10.100

TABLE 3-IB															
Parity of the second of the se	atini m.ij	1268** 760 108% 1786 : 246 1-1	H 1 (f ^{. 1}	1940 1940 1969 1969 1964 5-1	N N 10 * ¹	916 1690% 1611 1516 1516 1716	10 * 1	978 1800° 54 11% 37 B 10 4	4 • 10 ⁻¹	P14 1100* 49.5 114 40 1 14 1		P13 1800** 94 N 214 118 e 90 N	k 18*)	274 (2007) (104 (107) (107) (107) (108)	t 18-1
ten i	rvsi mirrons	6 X	N . 19.309	ξ <u>μ</u>	N a.	E.	16, 999	ξ.	14 B		N :: IV, 500	€# 199	N %	€ A 100	N o 10,000
\$150 - \$100 \$100 - \$100 \$000 - \$100 \$100 - \$100	1,1784-1,0608 1,0602-1,8780 1,0780-1,719 1,1717-1,0118 1,0114-1,313	0:00 0:11 0:17	0. (4) 10. 174 10. 143 11. 143	0, 1,00 0,63 17,00 73,61	0,018 41,108 07,611	11	iine	1.44	6. 6. 6. 6.	1111	9: 9: 9: 9:401		0. 0. 1.010 10.100	0. 0.01 1.16 10.07	1:11
110-140 1104-11- 1104-11-	4,3459-4,6166 4,4446-4,3678 4,3678-4,2553 4,2773-4,1007	17.01 17.71	1/2.561 79.174 179.766 199.766	66, 60 106, 90 100, 90 97, 88	100.10h 170.176 170.766	11.0	\$7.071 \$1.014 \$7.005	11:11	110.656 110.656	13:33	190.000	11:51	198.817 208.816 207.937 188.887	#: H	\$55.555 505.710 517.015 251.740
2000-1000 2000-1010 2010-1010 2010-1010	1,000-1,40/3 1,40/3-1,4/3; 1,4/3-1,4/3; 1,4/3-1,4/3; 1,4/4-1,4/3; 1,4/4-1,4/4;	1111	-9: -9: -7: -8:	-9:	1.000	-0. -0. -0.	. V. . V. . V.	-0. -0. -0.	-9; -8; -8; -10;	-0; -0; -0; -0;	· • · · · · · · · · · · · · · · · · · ·	****	-\$: -\$: -\$: -\$:		: 1:
1077-1079 1070-1079 1070-1070 1070-1070 1077-1070	6,7585-6,9761 6,7761-6,7167 8,7169-6,7878 8,7678-6,8788 8,8888-6,8788	133	-0. -0. -0. 0.047 0.210	1,37 1,49 1,46 1,63 1,63	# . 6 % # . 6 % # . 7 } U U . 7 % 1 . 1 } Ø	.6. .6. .0.			-#: -#: -#: -#:		-0, -0, -0, -0,		- 0 1 - 0 1 - 0 1 - 0 1 - 0 1		. 0. . 0. . 0. . 0.
1919-1914 1919-1944 1949-1944 1949-1944	1,8748-1,8015 1,9665-1,4511 1,5511-1,415 1,865-1,415 1,665-1,4174	1:17	0,00) 0,540 0,737 0,877 0,000	1.73 1.30 1.60 4.60 6.61	1.94 1.94 1.84 1.10 1.10	-9: -9: -9: -9:	-0; -0; -0; -0;	:#: :#: :#: :#:	-0. -0. -0.	- 0 i	• • • • • • • • • • • • • • • • • • •		: 0: -0: -0: -0:	\$; \$;	
\$447-1100 \$444-1644 \$449-1644 \$444-1648	0.0173-0.00ff 0.007f-0.750f 0.750f-0.750f 0.760f-0.753		1,112	1.75 1.67 1.77 4.77 6.14	6.686 6.886 6.981 1.661 1.11	-8; -6; -6; -9;	- 0; - 0; - 1; - 1;	.9. 0: .0: .1:		1111	.0, .0; .0; .0; .0;		1		0. 0. 0.000 0.001 0.007
#100-#100 #100-#110 #110-#110 #110-#140	a, fold-a, food a, food-a, food a, food-a, food a, food-a, food b, fold-a, food	1: 15 6: 36 7: 16 7: 87 8: 87	1. 111 1. 111 1. 111 1. 111	7,66 7,66 9,71 11,66	1.00	. P	. U. - B. - B. - B.	1	:0; :0; :0; :0;	1	:1: :1: :4:	101 01 01 01 01	16: 16: 16: 16:14: 16:11:	0.13 0.04 0.01 0.00	
#10-#110 #110-#110 #110-#110 #110-#110 #110-#110	6,7969-6,6968 6,6969-6,6848 6,696-6,677 6,677-6,6678 6,6678-6,6812	4.94 6.74 11.55 13.35 17.76	1, 176 1, 603 1, 603 1, 603	*****	7.81p 9.303 11.197 15.878 16.887	.0, .0, .0.	-0; -0; -0; -0;	-8; -8; -9;	•		8: 6:416 6:416 8:447	1.1	6.166 6.477 6.478	55533	0.416 0.016 1.016 1.55 1.55
#150-#155 #150-#155 #160-#155 #160-#155 #160-#155	1,011,-1,010, 1,014,-1,014, 1,010,-1,011, 1,010,-1,11,	90.10 90.10 90.10	11,740 15,780 15,073 16,000	11:11					1. 1. 1.11 1.40	1.33 1.33 1.33	1. 141 1. 141 1. 141 1. 144 1. 146	36333	1.181 1.181 1.181 1.181	1.07 3.00 3.00 3.00 4.00	1:41
#100-#100 #100-#101 #100-#100 #100-#100 #100-#100	1,1077-1,1077 1,1077-1,107 1,1707-1,107 1,1007-1,1170 1,1100-1,1170	\$6.00 \$7.00 \$7.00 \$7.00 \$7.00	(0.104 10.715 11.645 17.617	60.57 67.66 94.54 94.54	10.61	0.46 0.16 2.16 2.17 1.18	0.75 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.1	1.00			1.00		1: 1/1 1: 1/1 1: 1/1 1: 1/1 1: 1/1	10,00 16,10 15,40 12,66 66,67	\$. 967 \$. \$17 7. 433 \$. 194 19, 779
	4,3434-6,3347 4,534-4,3447 6,3744-4,5167 4,3747-6,3848 6,464-6,4848	99, 16 99, 78 99, 94 99, 19	11.017 11.022 11.102 11.040	16.67 99.06 160.00 100.60	10.75 10.76 10.16 10.16 10.50	#1.85 #1.15 #1.63 1.15 81.61	6.864 1.644 1.544 1.146 1.117	\$1.38 \$1.18 \$1.67 \$1.17	1,001 (1,01) (1,01) (1,00)	4:34	1 177 1.161 1.666 1.666 2.666		4:43	74.57 11.45 14.75 14.75	
	1,164,-1,181, 1,161,-4,171, 1,171,-4,481, 1,161,-1,181, 1,111,-1,181,	10, 00 100, 00 100, 00 100, 00	10,000 10,165 10,610 10,611 10,411	100.00 100.00 100.00 100.00	14.141 14.141 14.141 14.141	1.11 1.11 1.11		9.63 19.67 11.66 16.61	1,41) 1,400 1,110 1,471 1,471	18.78 19.61 21.18 21.18	6.764 9.166 16.664 11.664	11.13 10.06 14.11 11.11		31:55 11:35	69.611 69.164 36.667 86.615
	1,110 1,150 1,110 -1,120 1,170 -1,120 1,170 -1,120 1,130 -1,100	100,00	10,175 16,166 10,166 11,666 11,618	100.00 100.00 100.00 100.00	18.171 16.164 16.166 11.166	6,91 9,36 16,16 16,56 11,31	1.17	17.00	7:005 0:161 0:101 0:107 0:107	79.10 19.17 16.11 17.60	13.500 15.640 15.751 16,115	****		75.65 75.69 76.66 76.68	****
1011-1100 1100-1111 1100-1111 1100-1111 1100-1111	1,070-0,5000 1,000-1,100 1,100-1,100 1,00-1,100 1,101-1,100	100,00 100,00 100,00 100,00	11.64 11.64 11.66 11.66	199.64 199.69 199.69 199.69		11.00 11.03 11.03 11.05 11.05	1, 1/1 1, 100 1, 100 1, 100 1, 100 1, 100	04.15 64.15 64.15 14.77	1, 194 1, 974 10, 198 10, 198 10, 197	90.64 50.64 19.66 17.10	19,776 17,666 17,676 19,716 18,167	77.64 17.64 19.11	74.00 97.10 97.10 97.10 97.10 97.10 97.10	#4.15 #1.14 #1.14 #1.15	17.187 18.666 18.666 11.666 11.666
	4,5-76 6,1596 4,5-66 6,5740 4,5,40 6,1157 4,5107-6,1163 4,5783-5,5711	100.10 100.09 100.50 101.00	19,519 14,665 11,669 11,676 15,671	100 .00 100 .00 100 .00 100 .00	11.645 11.645 11.667 11.671	14.00 14.00 14.00 14.01	1.101 1.101 1.111 1.111	29.86 21.65 21.65 27.66	19.59 19.59 19.55 19.55 19.55 11.86	10.16 10.01 60.61 60.10 61.10	18.815 11.167 14.69 14.617 14.764	61.41 61.41 67.41 67.41	#1.154 W. W. W. 645 W. 645 W. 545	#	61,816 68,661 68,661 68,815
Mt- ht- ht- ht- ht- ht- ht- ht-	4.5611-4.2610 4.2416-6.2627 4.2624 4.223 4.273-4.2364 4.2844 4.2111	10. et 10. et 10. et 10. et	11,100	196.96 199.66 198.66 198.67	17,846 17,187 17,841 11,841 11,844	13.61 14.64 14.41 13.41	6.764 7.666 7.666 7.666 1.671	61.16 69.33 69.34 61.46 H.33	11.063 11.060 11.060 11.000	11.11 11.11 11.11 11.11	+0.100 +0.100 +0.001 +0.001 +0.100	17.11 17.11 17.11 17.14	90.411 90.754 10.751 10.111 10.111	60 (1) 60 (1) 60 (1) 61 (1)	48.111 47.413 41.464 41.374 21.444
2966 264 275 266 276 266 276 276 276 277	1,315-0,245 1,250-0,1-13 1,250-0,240 1,250-0,210 1,210-0,210	100.00	10,007 10,004 10,004 11,001	10 10 10 10 10 10 10 10	11.007 13.007 13.000 11.001 11.005	11,00 11,00 10,10 10,11		16,91 16,91 11,69 16,91	1,111 1 pts 1,111 1,111 1,111	11.14 14.75 14.15 14.15 14.15	10.101 11.617 11.617 11.717 11.717	11.47 11.44 49.11 11.11	24.864 65.868 16.861 76.861 76.861	14 15 17,24 11,04 11,04 10,19	00,000 10,100 10,010 10,010
1 151 - 1000 1 161 - 171 1 161 - 171 1 171 - 170 1 171 - 170	6,8166 6,0817 6,26176 1186 6,1666 6,1661 6,166176 1756 6,16618 1861	M. M. H M M	11.54 11.54 11.54 11.54 11.54	10, 11 10, 10 10, 11 10, 11	15, 515 15, 607 10, 514 11, 110	6.45 1.45 1.17 1.17	1.10 1.10 1.10 1.10 1.10 1.10 1.10	1.1. 1.91 1.91 2.91 1.91	1,155 1:11 1,51 1:14 1:15	13 64 14.43 1.41 1.41	1 101 1 101 1 000 1 000 1 100	H M	11.10	M.11 M. H. P. H.	15.151 -0.69 -1.200 -0.600 -0.101

TABLE 3-IC

	IABLE 5-10														
Sample No Tame I Pits P (mm Hg) p (CO)/P e (atmos re distribute) (c) Fig No.	**************************************	1900°k 1900°k 100 114 114 115 115	0.1	716 1200°M 749 41% 940 x 1 208 1-2	0.1	1980 a 1980 a 1980 a 1980 a 1980 a	10-1	F 18 1200"s. 26 10 14 8 16 0 11.1		F10 1200"M 67 14 88 16 6 0 21 8		# 20 1200 Ptc 94 16 NM 11, 8 w 91 4 1×5	o-1	Pel 1200°t 190 16 °49, 64 °t 74 °t 321	
em 1	mirr ans	100	N a 10,000	100	N e In. 000	E a	. N	€ #	N 9	45	19.900	€ ≠	N a 19, 999	E.# 100	N a 10, 300
1130-107 1130-1130 1100-1130 1100-1130	1,1989-1,0000 1,000-1,9600 1,060-1,610 1,610-1,611 1,619-1,511	0. 0.94 0.94 1.64 20.40	0.011 0.011 10.005 101.003	0 0.22 1.45 3.00 76 11	0. 9.371 1 046 (4.248 176.941	0.04 7.37 9.40 36.07	0. 5.710 11.100 10.107 271,102	0. 0. 0. n.la	0. 0. 0. 0. 5.5%	0. 0. 0. 0.4)	0. 6. 0. 7.	0. 0. 0. 0.00 1.30	0. 0. 0.001 6.550	0. 0. 0.11 - 1%	0. 11. 0.340 14.830
1370-170 1140-170 1140-170	6,6666-6,1678 6,9678-6,9553 6,9551-7,1667	91.17 11.11	17.410 140.117 17.441	100 fts 99.93 89.65	143.701 170.176 170.176	100,00 100,00 84,11	470.176 470.766 611,506	10.06	\$31,896 \$0,196 25,116	18.87	75.000 75.000 49.670 67.500	#3.#0 10.4# 15.##	176.467	37:38	114.171
1877-1870 1878-1877 1878-1877 1878-1878	5,0780-5,076 6,076-5,076 6,076-5,076 6,076-5,076 6,076-5,076	-D. -O. -D. O. O.Ob	0. -0. -0. 0. 0.	6 00 6,00 0 08 0 13 0 19	0,000 0,000 0,018 0 187 0 127	0.88 1.01 1.09 1.00	0. F50 0. F50 0. F15 0. F67	-11, -0. -11, -0.	-0. -0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0.	0. -0. -0. -0.	-0. -0. -0.	.0. .0. .0.
1012-1010 1003-2010 1003-2010 1003-2010 1003-2010	6,0100-6,0605 6,0605-6,0566 6,0546-6,0656 6,056-6,056 6,050-6,056	5.25 5.46 1.68 5.46	0.191 0.993 0.393 0.116 0.216	0,49 1,37 1,38 1,45 1,47	0,676 0,716 0,746 U,676 U,447	1:37	0.167	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0.	-0, -0, -0, -0,	-0, -0, -0, -0,	-0.	-0. -0. -0. -0.
1000-1100 1000-1017 1000-1017 1000-1017	u.mgrf-u.frap u.fraf-u.fraf u.fraf-u.frii u.frii-u.frii	1:16	0.111 0.140 0.440 0.440 0.440	1,00	0.71m 0.71m 0.41f 0.711	2,56 2,69 1,61 1,54	1.040	0. 0. 0.	0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0. -0. -0.	-0: -0: -0:	.0. -0. -0. -0.
\$100-\$105 \$105-\$110 \$110-\$112 \$110-\$120 \$110-\$155	u, fore-u, fife u, fife-u, fife u, fife-u, fife u, fife-u, fife u, fife-u, fife	1,17 1,20 1,10 1,41 2,11	0.444 8,818 0.431 0.947 1.144	133 133 133	1.08%	1.91 5.65 7.32 7.97	1,000 5,210 7,075 1,110 1,010	.0.	. U. . O. . O.	-0. -0. -0.	-0. -0. -0. -0.	.0, .u. .n, .n,	-0, -0, -0, -0,	-0. -0.	.0. .0. .0.
\$100-\$100 \$110-\$100 \$110-\$100 \$110-\$100	%, fnye-%, aek# %, 6fkg-%, 6ffe %, 6ffe-%, 6ffe %, 6ffe-%, 68ff %, 66fe-%, 69ff	1.01 1.05 1.17 1.41 6.18	1.471 1.741 2.744 2.444 3.444	1,47 2,47 6,67 6,68 10,46	7,150 7,420 1,246 2,109 5,870	11,14 11,14 11,43 14,41	1,518 1,547 6,661 10,061	-8. -6. 0.	0. 0. 3.	8 0 0	0 0 0 0	-0. -0. -0. -0.	-0, -0. -0. -0. -0.	0. 0.46 0.16 0.87	0. 0. 0.031 0.172 0.534
\$138-\$153 \$15" \$160 \$16. \$163 \$163-\$170 \$170-\$173	*,051;-1,0406 *,646-4,6546 *,656,610 *,6107-4,6505 *,6455-4,50ff	7,10 9,17 11,14 11,61 16,67	1,487 1,270 1,270 6,611	19,94 19,97 70,47 25,21 30,78	12.000 12.000 12.000	11:0	17.741 17.741 17.744 51.438 53.672	0 0 9 0 01	0 M/5 8 7 1	4 11 4 60 4 61	0 # 419 # 465 # 155	8,15 9,17 9,57 9,66 1,66	0,170 0,170 0,107 0,107	1 02 1 15 1 74 1 89	7 493 7 655 6 665 8 93, 1 119
\$169-\$100 \$160-\$100 \$160-\$100	0,3911-0,3611 0,3011-0,3701 1,3761-0,3601 0,3952-0,3334 0,3334-0,3833	76.76 29.36 39.36 15.11 86.79	0,505 15,700 16,155 15,166 20,007	18, 18 11, 17 18, 18 18, 69 81, 77	17.014 20.000 24.466 26.361 32.128	17.86 87.78 17.11 67.11	11, 246 11, 246 16, 715 46, 761	9 1) 9 1) 11 10 1 43 11 47	u 100 u 100 u 100 u 100 u 100	#, \$5 #, \$5 #, \$5 #, \$5 #, \$5	2.11 2.23 2.23	1.5	0.000 0.000 0.000 1.100 1.010	1:11 1:11 1:11 1:11	1.457 1.665 7-119 2.646 5.819
\$\$\$0.\$\$\$ \$\$10.\$\$\$0 \$\$10.\$\$17 \$\$60.\$\$10	0,5033 0,5353 0,5365-0,5365 0,5366-0,510 ² 1,5165-0,5665 0,5665 0,6760	\$6.49 \$6.67 \$4.68 .6.75 75.77	17.674 23.627 17.643 16.132 13.137	71,96 75,16 85,46 45,46 45,46	15,676 16,677 61,176 61,786	77.15 71.15 71.15 46.71	10.161 10.171 17.110 10.710	7.45 7.45 7.45 7.41	0,464 8,466 1,861 1,855 1,365	7.14 1.44 1.16 1.35	1.140 1.140 1.655 1.756 7.855	1.00 1.70 1.03 7.03 0.03	1,607 2,161 2,869 1,822 6,11	12.10	1.005 5.051 6.054 7.001 0.115
1142 - 1121 1142 - 1122 1142 - 1144 1140 - 1144	8,898 4,898 8,898 4,688 4,689 4,688 8,888 4,888 8,888 4,888	61.01 64.15 64.15 67.11	*0.145 *0.045 *2.5*7 *1.5*5 *5.1*0	96.76 96.11 96.11 97.46	16.417 17,311 16.417 10.480 11.616	100,00	10.161 10.161 10.116 10.116	1.37 1.71 1.10 1.00 1.00	1,361	6.00 6.00 9.00 9.21 9.34	2.406 2.467 1.468 4.614 4.384	18,97 17,16 16,10 19,15 19,15	1,874 6,868 7,116 8,857 6,778	20.00 21.07 20.75 10.05 11.11	0.07e 11.039 13,894 19.76f 14.31f
\$\$\$\$ \$\$\$\$ \$\$\$\$-\$\$\$\$ \$\$\$\$-\$\$\$\$ \$\$\$\$	6,8136-0,8546 0,8366-0,8546 0,856 0,0-52 0,8156-0,8551 0,805-0,1856	91.87 90.70 91.70 21.00	45,674 40,407 44,670 44,673	199,43 199,22 199,24 199,44	19,175 19,166 18,171 11,561	120 . 12 120 . 32 100 . 50 100 . 50	10,100	1.11 0.45 0.71 7.30 0.75	2.986 2.986 1.789 1.616 1.781	10,10	1,100 1,760 1,601 1,000 1,317	11.14 11.14 11.15 11.15 11.15	7,960 18,756 11,577 16,375	10.40 10.40 14.40 11.61	17,058 10,350 85,014 81,636 82,107
1100-1100	a 10% - 4, 1064 a 1064 - 4, 144 a 1164 - 4, 168 a 1666 - a 1171 a 1171 - a 1670	97.76 97.76 97.16 97.16 97.10	67,671 67,682 67,637 67,673 68,673	186,64	11.814 11.814 11.841 11.841	199.46	19.114	4.74 4.37 1.44 1.76 3.75	1.207 1.311 1.714 1.114 1.114	19.46 16.46 16.46 17.16 17.16	7,818 8,878 8,338 9,416 8,417	81.71 15.44 10.37 25.74 15.75	16.105 13.669 14.669 14.660 14.669	14.47 14.45 14.45 14.71 11.45	#1.750 #1.001 #1.311 #1.001
\$100 - \$100 \$100 - \$110 \$110 - \$110 \$110 - \$100	0.2678-0.1550 0.2500 0.5250 0.5500 0.5105 0.5105 0.5105 0.5105 0.5015	#	40.654 44.643 44.443 40.434 41.444	20 . 20 . 20 . 20 . 20 . 20 . 20 . 20 .	11,411 11,641 11,641 11,111	100.00	17,417 17,417 14,607 14,471		4.254 4.254 4.347 4.347 4.341	17,14 17,14 17,15 17,15 19,16	6,143 6,143 6,666 6,716 6,653	19,49 19,49 19,49 30,49	14,294 14,464 14,447 11,449	11.01 11.01 11.01 11.04	11.010 11.010 11.010 11.011
the the	6 4011-6 7716 6.7816-6.7527 6.2027 6.2725 6.2727 6.2006 6.2045 6.2011	89 19 99 31 91,14 97,95 11 12	61, 49 40,836 41,861 48,828 67,636	P(1) 11.55 21.11 61.51 51.77	17,347 17,374 18,847 19,111	100,00	17.101	10.07 10.07 10.07 10.07	1,140 1,140 1,140 1,100 1,100	10.00 10.17 10.50 10.60 11.20	0.248 4.515 6.515 7.611 8.444	11.45 16.46 19.45 19.16 21.17	15,495 15,465 15,666 16,666 16,77	\$,75 95,40 96,16 96,16 31,41	\$6.963 37.821 96.506 96.655 23,181
\$150-\$150 \$250-\$160 \$260-\$260 \$150-\$150 \$170-\$170	0.8555-0.0003 0.8555-0.8555 0.8555-0.8663 0.8565-0.8566 0.8565-0.8585	*****	11.500 16.103 11.001 11.001	\$1,67 98 1 14,50 99,15 89,51	10 404 10 407 10 17 10 17 10 17	100,54 100,56 101,56 100,56	17, E31 15, 161 15, 166 15, 261 27, E13		1, 101 1,000 1,000 1,001 1,101	18.81	0.15g 2,100 1,700 1,700 1,701	#1.86 #1.09 #1.15 #1.15	15,516 15,565 11,655 16,669 8,129	10.11 10.11 10.11	26.007 23.000 21.200 3.010 12.000
*143 100 *100 110 *100 110 *100 110 *100 110	0.2126 0.2414 0.2415 0.1625 0.1620 0.1601 6.1601 0.1750 0.1750 0.1601	12 13 14 14 12 13 11 15 11 15	24, 112 44, 231 91, 233 13, 354 1, 954	94,59 95,65 17,56 14 14	17 146 15 199 16 165 16 165 1.746	60 10 60 11 61 15 17 16 17 16	10.769 10.174 17.341 30.744 1.115	1.00	2, 41. 1, 942 1, 949 1, 949 6, 414	1.76 1.90 1.60 7.41	3 544 64512 1 063 1 263 6 7 16	11.11	1,150 1,200 1,160 1,160 1,160	111	19.041 8,816 6,117 1,001 7,001

TΔ	RI	F	3-	חו
1 /4				

	IABLE 3719														
Bempie No. Tomp. (*K) (* mon He) p (CO ₂)/F y (strike tin) Fig. He.	, बाह्म हक्त [े])	1200 14. 90 120 121 5-3		F41 1200°F 739 14.3% 250 n 162 3-3		1200°K 40 7, 65 8, 27 x 13, 6 3-4	ie. ₂	1200°1 94 7, 4% 16, 2 s 24, 3 3-4		72A 1200 ⁹ R 190 7, 49 32, fl x 44, 9 3-4	10-3	F27 1206 380 7.4% 69.7 76.9 3-4	K n 19 ⁺³	1200° 730 7. 6% 131 a 127 3-6	
em ^{e)} list	mieros	190	N . 10, 104	4 ×	N 7 18, 900	En 199	N 1 18,000	₹# 196	N = 10, 860	E 180	N # 10, 690	E # 100	H x 10,000	190	N a 10.000
1939-206' 2939-2168 2939-2138 2139-2268	5.1282-1.0000 6.0000-1.0780 8.0000-1.7614 6.7610-6.5312 8.0017-6.3833	0. 0. 0.01 1.25 7.01	0. 0. 0.033 0.073 34.161	0. 0.00 1.45 12.47	0. 0.490 7.050 40.6 3	0. 6. 0. 0. 0.	0. 0. 0. 0. 0.	9. 9. 0. 0.14	0. 0. 0. 0. 1.623	0. 0. 0. 1.01	0. 0. 0. 0. 1.703	0. 0. 0. 2.01	0. 0. 0. 0. 12.701	0. 0. 0. 0.53 3.05	0. 0. 0. 1.015 20.514
1100-1100 1100-1110 1100-1110	0.3055-b.00bb 0.000-b.30fB 0.8078-0.7553 0.8558-4.1667	30.76 72.14 77.35 10.26	179,966 151,076 307,338 276,003	17.11 92.02 95.75 63.37	274,365 651,128 664,460 328,671	7.65 7.65 9.85 5.87	12.889 37,432 48,347 28,647	3, 16 16, 51 18, 73 19, 61	25.723 92.440 51.188	9,97 97,67 98,79 18,71	136.632 185.323 185.325 91.622	19.27 98.33 36.28 31.29	732.002 732.002 774.073 153.615	11.0. 13.56 01.10 51.16	166.165 100.014 101.005 234.071
2073-2000 2000-2003 2003-2000 2008-2003 2103-2100	0.0171-0.60FF 0.00F7-0.F906 0.F906-0.F00F 0.T00F-0.F733 0.F83-0.F019	-#: -#: -#:	ii.	0. 0.0) 0.10 0.30 8.44	0.0 3 0.077 0.103 0.715	-0. -0. -0. -0.	-0. -9. -9.	-0. -0. -0. -0.	-9. -9. -9.	-0. -0. -0. -0.	-0. -0. -0. -0.	-0. -0. -0.	-9; -0; -0; -0;	# 10 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-0.
2100-2103 2103-2110 2110-2113 2113-2120 2120-2123	a. Fair-a. 7386 a. F386-a. F383 a. F383-a. F281 a. F281-a. F1F8 a. F1F8-a. F858	1.45 1.45	0.114 0.230 0.341 0.307 0.407	0.54 0.71 0.65 0.76 1.17	0.100 0.100 0.412 0.417 0.407	-0. -0. -0. -0.	·), ·0, ·8, ·6,	-0:	-0. -0. -0. -0.	-0, -0, -0,	-0. -8. -9. -9.	-0. -0. -0. -0.	-9. -9. -8. -0.	-0: -0: -0:	-0. -0. -0. -6.
#139-#130 #139-#140 #139-#148 #148-#145 #148-#145	1,7954-1,6418 1,648-4,6539 1,618-1,6774 1,6724-1,6678 1,6678-1,6578	1.87 1.89 7.00 7.23	0.66f 0.76f 0.01f 1.01f 1.01f	1.35 1.36 1.45 2.46 2.17	0.694 0.779 0.646 1.167 1.316	.0. .0. .0.	-0. -0. -0.	-0. -0. 0. 0.	-0. -0. 0. 0.	• • • • • • • • • • • • • • • • • • •	-0. -0. -0.	-0; -0; -0; -0; -0;	-0. -0. 0. 0.	0. 0.00 0.33 1.12 1.34	6. 6.037 6.767 7.353 8.766
1150-2155 1150-2165 1160-2165 1160-2175	1,0518-0,0290 2,020-2,0270 0,020-1,0147 0,0147-1,0403	1.07 1.08 1.30 9.11	1,919 1,871 1,746 2,161 7,407	3.10 3.11 7.20	7.916 2.926 3.424 3.447		0. 0. 0. 0.	0. 0. 0. 0.	0. 0. 0.	0. 0. 0.07 0.48	0. 0. 0.011 0.127 0.111	0.13 0.27 1.27	0.045 0.615 0.370 0.370	7.70 7.70 7.48 1.31	0.948 1.052 1.206 1.614 2.149
\$100-\$103 \$100-\$103 \$100-\$103 \$100-\$100	1,39ff-6,3f8 6,3f8-6,3f6f 6,3f6-6,366f 6,5f6-6,358 6,6f7-6,66f6	9.87 9.27 9.90 11.09 13.12	1.161 1.016 1.410 1.740 4.770	11.68 19.07 19.32 81.43 80.81	7.444 4.913 (0.614	0. 0. 0.11	0, 0, 0, 2, 0,121	0.16 0.81 1.05 1.55	0.070 0.070 0.777 0.111 0.718	1.91 1.16 1.88 2.87	0.708 0.017 1.117 1.272	7.16 1.16 2.16 3.16 4.17	1.167 1.67, 2.116 2.616 3.119	3.35 8.00 8.60 10.66 10.57	1.706 3.467 4.138 4.657 6.134
1110-1117 1117-1110 1110-1117 1100-1117	q, 5055-0, 555; a, 5551-0, 560 a, 5565-0, 566 a, 5107-0, 5645 a, 5645-2, 5645	17.18 20.71 21.16 10.01 11.60	0.000 10.000 11.000 10.000	10.47 20.13 40.13 40.13	13.051 17.657 20.440 25.410 24.387	9.71 9.91 1.11 1.11 7.11	0.103 0.103 0.104 0.736 1.032	7.07 7.03 1.22 1.05 1.05	1,614 1,749 1,354 1,441 2,204	1.36 1.48 1.17 1.17	1, /1/ 2, u/1 1, 01/ 1, 01/ u, 188	7,68 7,58 11,51 11,71 16,16	1.717 1.010 1.023 6.761 7.007	15.85 18.16 21.51 25.63 10.47	f.usn u.su 16.sig 16.seg 14.69
110-110	1,0905-1,084 } 1,740 }-2,149 1,540 }-2,149 1,540 }-2,240 } 1,550 }-2,250 } 1,550 }-2,250 }	10.00 10.00 10.01 11.11	19,027 21,039 21,039 26,102 26,103	44.33 44.36 77.66 77.65	17.654 17.661 17.655 18.111	7.40 7.53 5.00 6.57 5.16	1,321 1,678 1,950 2,250 2,318	0.13 0.76 7.80 7.80	1,600 1,000 1,100 1,000	11.00	0.760 0.860 7.770 0.760	11.01 11.01 14.01 16.11	11.765	13.75 46.77 43.46 10.43 34.16	17.017 17.017 17.117 11.141 11.144
110-111 110-110 110-110 110-111	1,0445-2,4366 2,4346-2,2698 2,4643-2,4136 2,4136-4,4633 4,4131-4,1736	60.00 60.00 60.10 70.06	10.016 12.560 15.601 10.155 15.150	00.15 00.15 00.11 01.11	41.774 43-149 44.334 44.749	9,69 8,19 9,68 7,16 7,48	8,705 1,831 1,775 1,520 1,704	10.22 11.30 12.60 11.00 11.74	.004 5.642 105.0 100.0 1.017	19.44 17.17 19.84 19.71	0,491 19,740 19,181 19,951	97,90 91,70 93,07 96,00	10.407 77.014 77.014 71.744	60.37 60.37 67.66 71.55 71.75	14.124 14.123 14.287 14.862 15.862
117-1100 1100-1101 1100-1101 1117-1100	6,3010-6,1868 6,3060-6,1764 6,3764-9,3666 6,3668-6,1373 6,3771-6,3678	71.45 76.51 73.06 71.45 78.71	\$6.127 \$7.673 \$7.722 \$6.106 \$6.40	93.11 94.81 94.81 93.17	49.565 46.121 46.005 47.001	0.10 0.47 0.63 0.76 0.76	0.105 0.105 0.210 0.200	19.98 16.87 18.57 18.97	1,687 7,069 8,136 8,348 6,567	\$9.93 \$9.93 \$0.03 \$1.30 \$1.30	10.649 15.176 15.476 15.476	58.54 57.54 52.51 56.55 56.57	1.11) 1.11) 1.11)	78,64 76,76 96,01 96,97	14.078 34.557 34.165 37.562 57.511
#100-#101 #103-#110 #110-#111 #115-#111	n, 5076-n, 5500 n, 5500-n, 5500 n, 5500-n, 5107 n, 5107-n, 5105 n, 5103-n, 5011	77.33 79.33 79.33 99.33 99.33	10.111 10.111 10.111 10.111	94.11 94.11 94.81 94.81	46.778 47.173 46.813 46.863 47.864	9.35 9.35 7.36 7.36	0.560 0.560 0.567 0.007	10,88 17,61 17,68 17,18 10,66	6.773 6.364 6.735 6.737 7.187	11.74 17.47 17.46 11.46	15.541 15.541 16.556 16.636	33.47 33.47 33.73 33.74	\$6.646 \$7.418 \$7.347 \$6.644 \$7.445	79,48 81,48 80,15 80,38 81,71	19.049 19.074 19.110 19.110 10.100
	a, 3011-a, 3018 a, 3016-a, 3057 a, 3057-a, 3123 a, 3130-a, 300a a, 300a-a, 3033	01.00 00.00 00.00 01.11	10.071	91.51 90.55 90.50 90.71	47 647 47,363 47,116 47,745 44,459	10.40 10.16 11.60 11.60 10.16	0,161 6,183 5,611 6,617 9,685	19.16 28.61 28.66 27.16 17.26	0,876 18,716 19,850 16,360 7,168	11.00 10.00 11.11 10.21 11.05	17.041	\$6,59 \$8,18 \$7,69 \$4,50 \$1,65	27.502 20.525 20.611 20.711 20.711	81,76 83,17 83,13 83,17 81,17	40.110 61.010 60.010 61.110 10.030
#150-#155 #155-#166 #160-#765 #165-#176 #179-#175	1,2551-1,2001 1,2001-1,2001 1,2172-1,2202 1,2172-1,2100 1,2174-1,2103	70 .00 70 .00 84 .00 83 .17 15 .46	17,410 16,759 11,662 11,667	#1.11 #1.11 #1.11 #1.11	40.465 41.465 44.465 45.465	19.79 11:10 16:02 0:11 6:16	1.162 1.615 1.211 1.177 4.022	11.77	1,496 6,475 1,736 1,736	15.49 16.30 16.37 46.30 27.03	16.343 16.469 16.960 16.960 16.163	11.60 11.60 11.61 11.71 17.86	##. 949 #8. 355 #8 75 #1. 600 19. #96	41,17 19,77 19,66 19,68 61,61	57.661 67.650 67.650 58.765 11.650
#171-#100 #100-#100 #101-#170 #101-#170	0,0105 0,0017 0,0017-0,1000 0,1000-0,1001 0,1001-0,1750 0,1750-0,1007	11.00	\$2,170 16,718 11,662 8,000 1,670		15.797 24.162 21.115 15.689 1.474	1.0	7.174 1.104 9.041 8.441	1.15	0,761 1,815 1,110 0,117	11.46	0.100 1.011 1.740 7.201 0.110		10.655 10.656 0.775 1.750	11.11	26.167 26.444 13.441 4.119

TABLE 3-IE												
Rer ple Nu - tomp PeR - hom light p (CC ₁)/P u (sinfle on RTP) - delaye on RTP) - fel Ne	929 1200°H 1700 7 4% 263 4 10 ¹³ 167 3+4	F10 160°K 3 100°K 26 % = 10 ° 3 37 ° 0 10°K	F1) (100°H) (100% 45 6 4 10 5 1+6	F15 1400°R 46 4 1000°R 87 8 4 10 11 18, 8 118	F31 364 TK 10 10 Tk 17 0 0 10 12 12 7 3 4 N	P16 180°R 189 1885 557 ± 10 - 3 184 3+3	F15 1404 N 1404 N 1404 N 117 w 10 - 3 236 3-5					
(merve) cm ⁻¹ microse	110 10 000	Est N m 100 10,000	EA N 1 100 10,000	ŽA N.V. 100 10.000	₹1 N ± 100 (0,000	EA N = 10,000	€2 N s 100 10,000					
1980-2930 h.1289-h.0000 1980-2730 h.0000-h.2760 1980-2730 h.7610-h.7610 2180-2130 h.7610-h.7610 2180-2230 h.0517-h.7610 2180-2230 h.0517-h.574 2181-2100 h.3813-h.4844 2101-2730 h.3813-h.4844	8. 0. 0. 0. 1.33 0.19 11.93 0.19 11.93 0.1983 10.24 17.193 17.83 17.193	0. 0. 4. 0. 0. 0. 1.00 0.010 1.70 0.010 0.10 00.007 10.01 103.010 10.00 100.020	6. 8. 8. 8. 9. 9. 9.19 1.186 5.05 55.197 16.05 196.185 28.29 291.012 15.06 287.012	8. 8. 8. 6. C. C. C. 9.70 0.381 8.50 27.999 11.10 277.008 47.17 019.009	0. 6. 0. 0. 0. 0. 0.50 14.874 ci '0 182.428 bq.00 680.830 71.60 887.016	0. 0. 0.12 0.067 1.40 11.868 7.60 05.151 57.35 526.758 70.87 206.261 91.27 405.165	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0					
3150-100v 0.3551-0.1567	71,64 447,645	7,36 40.7.3	12.1 1-0.401	19.01 100.000	10.70 115.441	10.15 110.167	79.10 677.000					
#"eh 781, 4, 9345-1, 5561 2618-2814 1, 5661-1, 514 2014-2814 4, "1604 9826 7818-281, 1, 1803-1, 1800 7818-281 1, 1800-1, 1852	18: -3. 0: -9. -0: -0. -0: -0.	-0, -0, -0, -0, -0, -0, -0, -0,	-00. -00. -00.	-0, -0, -0, -0, -0, -0, -1, -0,	16: 16: 16: 16: 16: 16: 17: 16: 17: 18:	0.02 0.010 0.02 0.010 0.03 0.100 0.10 0.101	0.01 0.000 0.16 0.121 0.10 0.100 0.17 0.160 0.17 0.170					
1000-2003	- 10	-0, -0, -0, -0, -0, -0, -0, -0,	-8, -8, -8, -8,	**	0 0 0 0 0 0 0 0 0 0 0 10 0 110	0.07 0.001 0.76 0.011 0.00 0.767 0.01 0.770 1.02 0.055	1.87 1.000 1.70 1.001 8.10 1.700 8.4. 1.007 8.53 8.190					
#6/6-4 480	10. 0. 10. 40 10. 15 10. 15 10. 10.	18. 40. 18. 17. 18. 17. 18. 17. 18. 17.		\$ \$1, -7 44, -7 44, -7 44, -8, 44,	# 21	1.07 1.000 1.07 1.000 2.10 1.017 2.10 1.017	F.*6 :. 198 5.56 F 255 6.15 1.509 5.66 5.203 5.76 5.912					
\$186-\$105	7.86 8.878 8.15 8.878 0.67 9.586 8.60 - 756 8.78 3.861	• 8	.BUUUUUUUUU.	C.mp 0.002 C.mp 0.007 C.mp 0.007 C.mp 0.007 C.mp 0.007	1 u5 1 210 1 00 1 500 2 17 1 904 2 01 2 06 1 3 17 2 005	1,65 2,505 1,16 2,691 1,10 1,156 1,10 1,156 1,01 1,156	8.00 3.079 8.11 6.006 9.55 8.566 11.65 9.775 11.66 11.661					
#130-#150 u.#NAd-b.even #130-#130 u.b-60-m.6610 .115 #160 u.be60-m.6620 #140-#150 u.bff0-b.6640 #185-#150 u.bf 50- 55- 85-#	1,27 0,503 1,00 -,115 2,24 1,600 2,74 1,601 1 10 1,607	*** **********************************	18. U. 8. U. 0.07 H.05P 0.65 9.170	C.45 0.527 0.01 0.705 1.25 1.075 1.51 1.360	1.00 5.350 5.50 5.000 7.53 6.730 6.70 5.750 6.10 6.073	7,14 6,114 4.64 f.468 19,46 9,173 19,45 17,74 18,47 13,414	16.44 18.465 16.21 16.615 28.61 16.606 20.46 26.512 16.66 26.676					
#150-#155	5,16 1,314 5,25 7,17 6 10 1,011 7,10 1,000 6,70 1,100	0.6 8.618 4.85 8.428 8.46 0.686 4.01 4.408 1.48 1.557	1,10 1,176 1,70 1,110 2 16 1,071 2,76 4,071 1,17 2,565	7:71 7:516 1:86 1:356 5:66 5:376 6:27 5:-1 7:41 6:416	0.83 0.563 11.57 0.661 12.69 11.670 11.60 11.753 18.65 18.607	70,17 15.060 21.60 18.740 25.60 26.150 27.50 25.607 50.11 27.575	18.00 18.180 18.6. 18.180 18.57 18.00 18.07 18.00 18.07 18.00					
#174.#160	10.14 3.513 15.61 6.761 16.66 8.275 76.71 16.100 76.71 17.000	1,72 1.494 2.10 1.024 2.41 2.105 2.04 2.441 1.85 2.724	1,00 6,270 6,72 4,100 1,67 4,604 6,75 4,647 6,41 7,716	1.00 /.100 17.00 9.00 17.01 11.100 14.07 11.200 17.00 11.000	\$1.40 19.500 24.40 21.600 29.27 24.60 31.60 27.707 35.73 31.214	19:01 81:000 83:00 60:715 00:00 02:571 83:74 03:000 88:50 81:101	95.95 55.550 18.69 57 560 18.96 66.155 96.55 26.750 96.65 76.770					
######################################	79.45 14.581 18.61 14.664 18.16 17.741 18.16 27.521 18.16 27.521	0,14 9,046 9,17 6,730 6,11 9,153 7,10 6,607 6,61 7,611	10,50 0,000 10,50 0,000 12,59 10,000 15,11 12,500 10,10 (5,251	19.00 17.100 27.10 15.701 27.10 27.101 27.10 27.100 19.01 28.300	19.83 16.87P 19.59 16.120 17.20 17.403 16.41 16.710 16.41 18.031	88:38 ->:38 88:81 ->:58 FP:61 698 P8:65 67:301 F0:51 69:005	04.20 Pr.108 91.11 F0.089 91.04 02.108 91.07 91.000 00.07 91.100					
###1-7#98	10,10 (4,713 10,00 10,101 11,00 10,101 11,10 11,000 10,10 10,131	0,50 4,550 10 17 0,650 11,65 10,550 11,50 11,610 11,50 12,500	18.81 18.868 18.41 17.666 21.60 14.071 22.03 28.251 26.10 27.109	11.10 29.180 15.07 11.451 10.10 15.772 16.16 15.020 11.61 17.000	17,00 10,010 10,10 12,007 11,12 11,112 01,00 17,110 01,11 11,010	07.00 78.05% 01.07 70.009 00.01 70.076 07.07 77.009 09.77 76.009	07.00 00.150 07.00 00.070 00.00 07.110 00.10 07.700 00.07 00.070					
#\$10-#\$25 4.0004.0.0104 #\$51-#\$60 4.0100-0.0\$60 #\$00-##05 4.0#06-0.0110 #\$41-##\$6 4.0100-0.0\$5 #\$\$1-##76 4.0100-0.0\$5	86,16 45,175 86,51 41,655 81,60 41,661 45,64 41,660 93,41 41,763	15.16 15.65 16.65 16.756 16.67 16.755 17.67 15.107 17.10 15.101	#1.74 #1.779 #1.41 #1.759 #1.41 #1.759 #7.40 #1.158 #6.47 #1.400	11.54 10.574 14.68 19.674 14.50 11.180 18.18 11.876 18.18 11.611	\$0.72 \$1.70% 75 \$0. \$2.004 71.15 \$0.00% 71.17 \$5.702 72.70 \$5.702	01,02 00.070 01.02 01.04 05.01 02.50 05.01 02.271 03.00 05.700	00.00 00.000 100.00 00.700 100.00 00.007 100.00 00.750 100.00 00.001					
######################################	15.11 13.279 16.11 17.137 16.17 11.778 16.11 17.138 17.18 17.138	17.08 15.708 17.97 16.052 18.21 15.275 18.10 15.197 17.40 16.031	#1.38 #1.761 #1.10 #1.108 #1.77 #1.108 #1.10 #1.108 #1.10 #1.108	10.67 11.100 10.15 11.100 11.15 11.107 11.15 11.151 11.17 11.151 17.17 11.161	71.26 45.164 74.65 44.662 71.61 47.774 74.61 47.474 74.61 47.400 74.64 48.611	95.17 93.976 96.46 96.593 96.65 96.579 96.17 96.565 95.11 95.196	100.00 00.167 100.00 40.078 100.00 00.074 100.00 00.074 100.00 00.101					
2808-2105 4, 1470-4, 2504 -101-2516 4, 1540-4, 1570 2510-, 213 4, 1740-4, 1107 2515-2220 4, 1107-4, 1101 2124-2320 4, 2107-4, 2711	10.05 67.550 17.56 67.751 10.71 07.050 10.10 17.550 10.10 17.570	17.00 15.005 17.00 16.015 10.10 16.005 10.07 16.001 10.07 16.070	30,50 34,550 30,01 30,019 30,550 27 551 40,12 37,347 30,01 07,000	10,00 41,010 10,00 15,102 11,11 41,121 11,11 40,351 11,11 40,351	78.08 05.768 75.06 01.055 75.01 10.055 77.01 01.505 77.18 03.576	05.64 85.175 15.61 05.077 95.07 85.755 96.71 05.761	100.00 01.000 100.00 01.00 100.00 01.00 100.00 01.00 100.00 01.00					
\$184-2510 0.1031-0.2010 \$530-2511 0.2010-0.2027 \$131-2510 0.2110-0.2027 \$101-2510 0.2110-0.2510 \$101-2510 0.2000-0.2510	No. 80 (7.300 17.17 (7.370) 17.10 (7.370) 17.00 (4.01) 17.00 (4.01) 17.00 (7.75)	19,50 10,724 19,15 17,766 10,00 17,150 10,01 10,075 10,00 15,500	10.50 27.51q 10.51 27.550 27.60 20.751 20.77 76.555 26.25 23.85p	19.65 41.111 45.67 41.467 41.49 43.411 41.67 41.410 41.14 37.376	15.00 14.000 15.15 47.000 11.00 00.005 00.00 41.227 65.40 40.177	#1.64 #4.61 #1.75 #4.61 #1.75 #2.75 #1.46 #4.55 #1.46 #4.55	100.00 00.177 100.00 00.271 100.00 00.271 00.00 00.00 00.00 00.00					
\$150-\$150	#7.00 67.483 97.02 67.623 98.64 66.883 98.65 66.872 98.65 66.872	10.05 10.200 11.00 12.075 11.05 10.000 10.07 1.200 0.07 1.400	#8.46 #1,411 ##.44 ##.#11 16.14 1#.158 16.46 16.158 19.77 17.768	17.69 bs.bs.7 36.15 12.667 41.65 24.165 26.56 25.678 27.58 25.578	\$1.55 15.825 \$2.65 16.725 \$2.65 17.225 \$2.65 17.616 \$6.65 17.855	00.00 /f.01/ 00.01 /2.00/ 70.11 /0.105 /2.21 00.000 07.27 01.210	50,81 00,748 50,51 00,748 00,61 07,744 00,61 01,458 00,00 00 111					
#174-2500 0,#105-0,#617 (80-7505 0,2017-0,1070 #360-2700 0,1070-0,1001 #360-2700 0,1001 0,1750 #360-2700 0,1750 0,1801	06.48 47.501 75.67 16.650 55.61 67.251 10.66 17.676 7.65 1.557	\$100 \$100 \$100 \$	0.40 0.73 7.10 0.457 6.40 1.757 5.46 1.177 1.13 1.054	15,10 12,044 16,71 11,044 6,85 4,216 6,11 5,64 6,12 6,135	\$6,60 \$1,070 \$5,60 *19.050 \$1,60 \$1,670 \$1,00 \$10.000 \$1,00 \$1,000	\$2.00 80.056 \$1.07 \$1.00 \$7.17 \$1.00 \$7.12 \$1.75 \$3.00 \$1.01 \$1.00 \$1.05	95.96 50.725 75.67 06.971 51.19 60.715 61.11 65.695 10.00 11.056					

TΔ	RI	F	3-	F

	TABLE 5 II														
Ampie He Imp [24 Inn 14] I to 17]	e de	716 1940*1 719 1990 1911 •	к К ^{-†}	1400°; 1645 1665 2660 ; 115	. 10 ⁻¹⁻	F18 1900*9 8 4 17% 1 64 4 9 18 1 68		1140°1 1140°1 114 114 1154 1154	1•·¹	1980 1980 20 N 19 M 19 M	16° °	761 (666*) 68 1 68 1 17 1	. 10 * 1	F42 940*1 	, . 1
<u>'</u>	mir (44a	2.7	N s	4 t	H	£ 4		4.	N 8	Ž =	N 4	£ .	,;;	Žr im	H
1: \$4-2000 -00-2450 2050-2150 2160-2150 2150-2150	\$.1202-3 0000 \$.0000-0.0700 0.0700-0.7619 0.7619-0.0519	1111	8. ,u3 9,300 10,361 755,067 710,344	#.#1 1:34 11:34 13:33 13:33	1.719 70.126 110.307	0. 0. 0. 3. 0.33	: : : : : :	1:41 1:41	0; 0; 0; 0; 12,340	0; 1; 2; 2;44	*: *: *:	1 2 41 1 10 1 01	0 0 0 0 0 0 0 0 0 0 0 0	: : : : : : : : : : : : : : : : : : : :	4 . ; ;;; 10 e); 100 f)4
1 170 - 1794 1 140 - 1 149 1 144 - 1 148 1 140 - 1 148	1,5052-2,4226 0,4467-0,5058 1,5058-0,5236 1,502-6,1665	20,77 100 00 100 00 100,00	177.000 101.109 761.500 760.07		879.862 890.951 981.178 860.181	7.17 7.15 7.16	10.100 12.100 16.101 10.111	10 17 10 17 12 60 1 80	31 Fed 91 MM 180 613 63 633	15.27 26.51 26.97 2.72	105,070 100,700 107,078 60,274	\$1.5% \$6.7% \$6.77 55.76	107.110 101.177 110.275 101.773	16.47 14.17 11.66 15.11	101,717 101,771 117,171 117,171
1975-1988 1989-1985 198-1985 1996-1995 1975-2588	1.00 51-5.0100 1.0505-3.0574 1.0574-4.0251 1.0231-5.1125 1.0139-4.0000	# 230	1	10: 0:#1 1:/1	-8. -9. -9.161 -2.168 -9.970	***	:1: :1: :1: :3: :1:	****	4. 4. 5.	***	-0, -0, -4, -5,	.0; .0; .0;	-1. -6. -7. -6.	4444	*** *** ***
1412-1414 1412-1414 1413-1414 1413-1414 1413-1414	3,0000-0,0013 0,0073-0,015 1,0751-0,0016 1,0074-0,0583 1,005-0,0141	9, 16 9, 11 9, 48 9, 65	2, 113 6, 507 6, 507 6, 507 6, 507	5.07 2.11 1.60 2.07 1.15	1,14+ 1,74+ 2,8+ 2+125 2+18	***	• V • • • • • • • • • • • • • • • • • •	•		.0. .0. .0.	-8. -8. -9.	 	•	1	
120, 1909 1910-1901 1910-1901 1211 11-12	1,0131-0 0761 1,0-61-0,0150 1,0100-0,0000 1,0020-0,0000 1,0000-0,5700	111	0.681 1.865 1.361 1.670 6.81		\$.00f \$.\$6) \$.33 6.310 8.410	#: #:	1. 1. 1. 2.		18. 18. 18. 18.	-1. -1. -2.	: † . : † . : † . : † .	0. -0. -0. -0.			8. -2, -6,
1855-2648 1855-2648 1848-2644 1845-2678 1879-3673	1,8502-1,8663 1,4662-1,8541 1,4749-1,8136 1,5171-1,8134 1,549-1,8171	1,57 1,62 1,13 1,88	1.10° 1.10° 1.704 0.701	6,89 7,87 8,98 18,15 11,12	9.769 6.587 7.669 6.587 9.676	1	· · · · · · · · · · · · · · · · · · ·	****	:	**	6, -1 -7, -3,	101 101 101 101	-6. -6. -6. -7.	0.00 0.10 0.11	*0. 0. 0.001 1.000 2.011
2073-2040 2074-2043 2074-2073 2073-2073 2783-2140	4,6:93-4,00 FF 4,50 FF-4,73 pg 4,70 QF-4,75 q 4,75 QF-4,75 q 7,77 S-4,79 FF	12.11	1.001 .502 7.670 6.52'	11.11	11.044			•	*** *** *** *** ***	3. 3. 3.	- 3. - 1. - 4. - 4. - 2.	:		8.44 8.49 6.63 1	4, 1/1 8.167 8.748 8.675 8.128
F186-2185 F186-2118 F116-2113 F115-2118 F186-2125	a, fa 10-x, faqa a, fakq: a, faq a, fa03-x, fax) a, fa03-x, fax) a, fa03-x, fax	13,13 14,46 14,97 31,19 41,17	19.661 19.166 18.166 18.165 21.754	71.07 71.70 11.00	//. 444 /b. 446 /b. 441 /d. 118		** ** ** **		1. .e., 1. .e.,	•	-1. -1. -1. -1.	# 10 # 10 # 13 1 ##	9 233 2 455 2 457 2 607 1 600	1,30 1,10 1,10 1,00 1,00 7,66	6.6e8 1.8.8 1.817 1.579 1.727
#191-#190 #190-#190 #190-#190 #190-#190 #190-#190	1,7650-0,6008 0,8000-0,6616 1,6650-0,8770 1,6770-0,6678 1,8070-0,8777	37.00 5.17 7.19 7.19	\$1.448 \$1.418 14.542 14.542 14.543	M. M. 17.16 40.11 11.61	69, 179 69, 181 56, 66, 69, 181 67, 181		• • • • • •	1; 1; 1; 1; 1; 1; 1;	6. 6. 6.321 2.110 6.279	2.46 2.47 2.37 3.76	1,076 1,171 1,111 1,111	1.49	1,110 1,240 1,327 ,100	2 10 2 10 2 02 3 02 3 02	1 921 1 92 2 92 20 30 1 93
2130-2133 2133-2134 2130-2134 2130-2174 2170-2173	1,012-1,016; 1,000-1,000; 1,010-1,000; 1,010-1,000;	31.14 31.14 11.14 11.14	10.000 11.00 11.00 11.00 10.00	#1.64 #1.15 #1.15	FB, 118 Fb, 189 FB, 848 BB, 848		1. 1.17 1.17 1.18 1.18	1.68 6.66 6.67 7.15	6 417 1:461 6:667 8:657 1:676	1.15 1.15 1.16 1.16	1, 441 1, 308 1, 519 1, 736 4, 213	2.47 3.50 5.41 5.47 0.48	1, 107 1, 177 2, 934 1, 358 1, 845	1 MB 4 MB - 1 MB - 2 MB - 1 MB	1 M 2 M 1 M 1 M
2175-2124 2160 2165 2160-1162 2160-2125 2150-2260	1,1977-0,5672 2,7672-0,767 6,774-0,5662 1,1662-0,5556 4,7550-0,5553	#::33 #::33	fg, 8 20 fg, 575 6f, 566 6t, 661 65, 566	11111	65,065 96,666 67,067 67,777 87,761	3.33 3.21 3.33 1.33 1.33	6,481 6,617 6,677 6,674 7,681	1.04 1.54 1.24 1.34 1.47	1,150 1,361 1,730 5,551 5,166	1,49 1,70 1,70 5,40 3,10	1,128 1, 79 1, 8,1 1, 8,1 1, 7,2	1.66 6.68 7.64 7.75	1,816 1,77 1,007 2,270 0,75	3.5	11 MM 12 Mm 12 Mm 17 114 18 MM
200-42-5 200-44-14 201-44-14 201-44-14 201-44-14	4,414,121 4,514,564 4,546,514 4,4 67-6,564 6,564	79.91 91.65 91.72 181.86	00.002 00.070 07.170 07.761 07.850	100	87,344 87,344 87,843 87,844 87,843		1,142 1,142 1,437 1,649 2,649	27.7.2	1 man 1 118 1 man 1 man 1 man	8.10 6.12 8.10 8.77	1. 524 1. 524 1. 538 1. 548 1. 548	15 el 16,04 18,67 19,45 28,14	11, 576 12-743 14-626 16-636 17-648	41.8 11.8 11.8 11.0	#1.730 #1.331 #1.230 #6.317 13.001
##10-### ##10-##1 ##10-##1 ##1-##1 ##1-##1	0,0000-0,0001 0,0000-0,0101 0,0101-0,0001 0,0000-0,0101 0,000-0,0101	M. M M. M M. M M. M M. M	10.16 00.16 00.19 00.100 00.111		56, 242 66, 142 66, 213 66, 250 66, 250		1.465 1.465 1.465 1.465 1.461		3	(4),44 (5),27 (4),54 (4),18 (7),88	15.161 16.161 1.161 11.1667		10,460 81,191 84,736 PL,416 PL,416	14.00 14.17 14.11 14.11 27.14	35, 713 66, 77 61, 854 68, 878 63, 486
2014-3814 2111-214 2111-2214 2111-2214	6.0000-0.1260 6.0000-0.0260 0.0200-0.010 6.0124-0.0013 6.0000-0.0056	184 62 24 64 144 64 186 64 186 67	60,027 60,764 60,567 60,056 81,767		10.0 f 14.768 20.056 31.050 01.653	133	0.845 0.864 1.874 0.174	1.0	1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	19.11 11.11 17.80 77.97 98.13	19. 857 19. 857 17. 867 19. 117 19. 117	10.01 19.17 17.12 11.13 11.13	7 . 605 64.656 65.717 76.746 61.66	17.16 11.61 12.17 54.16	14.100 17.100 11.100 11.100 11.200 11.27
1175 1164 1109-1544 1109-1544 1171-1545 1171-164	a, prag. a, soud a, soud-a, sras a, sras a, saos a, suad-a, sars a, sars-a, sars	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	64. 979 64.979 64.576 64.576		00 137 01,01 01,00 11,00	1	1,201 1,202 1,100 1,10°	18.45 19.17 19.16 17.16 18.18	9,113 1,319 1,319 1,120 1,120 1,181	21 Mg	16.100	N . 18 N . 11 N . 13 N . 13	10,670 11,180 11,800 11,761 15,175	30.71	100.116 10.110 10.100 10.101 10.111
2 600 - 2 601 2 600 - 2 611 2 6 10 - 2 611 2 6 10 - 2 611 2 6 10 - 2 612 2 6 10 - 2 612	0.5078 0.1400 0.5300 0.5000 0.6500 0.5477 0.5107/0.5777 0.5155 0.5541	1 1 2 2 2 2	04.765 04.765 04.905 91.156 54.704		04,671 05,771 46,671 36,771 91,474	1.3	1.444 1.444 1.175 1.581 1.681	17. 18 17. 19 11. 13 14. 15	0,000 18,754 18,555 18,565 19,566	#1:Pe #8:2* #4:** #1:**	18,658 - 90,641 96,666 70,581 71,588	95 - 64 10 - 64 17 - 66 17 - 66 18 - 11	H, 100 H 1 H 11.00 11.00 H 11.0	\$0.51 84.31 81.49 81.41	49.000 50.000 50.000 50.000 11.561
1 beg 1 beg 1 beg 1 beg 1 pe 1 1 1 d 1 pe 1 1 1 d	4.9814 4.2818 4.2816 4.2887 4.2884 4.2837 4.2844 4.444 4.2844 4.284	11111	12,177 107,973 106,764 101,16	10.00	49, 194 41, 244 11, 164 41, 156 18, 156	1.5	6.600 6.600 6.600 7.600	10.13 10.13 10.13 10.15	11 447 11 147 11 147 1 217	# # #.# #.# #.# #.**	f1.00. ff.0fc ff.agf f.00 f0.is6	19 (7) 10 (19 17 (19 18 (19 10 (19 10 (19)	16.15. 16.15. 16.15. 16.150.		16.567 16.530 10.560 11.111 16.001
\$ \$50. \$310 \$ \$50. \$310 \$ \$50. \$310	a. 255 b. a. 2541 a. 265 s. a. 2217 a. 2123 c. a. 221 a. 220 c. a. 210 a. 220 c. a. 2125	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	48.944 69.151 97.842 96.600 17.100	# # # # # # # # # # # # # # # # # # #	10 144 151	1:2	8 724 3, 868 6, 738 1, 697 6, 633	1, 10 1, 11 1, 11 1, 14	1 pq 1,770 1,780 1,351	16.56 6.51 16.56 17.56 17.66	14 \$4.5 14 14 14 146 15 146 16 155 1		(7. pet) 84 - Pet 89, 184 14, 841	55 18 57.96 52.47 56.76	11.191 12.91 20.790 11.11 21.11
\$100 515 \$100 1927 .400 1906 \$100 5702 \$112 1900	8.8 08.0.pd-1 0.28.1 0.1050 0.1050 0.1051 0.1051 0.1550 0.1750 0.1650	10.00	15,665 15,666 76,175 67,188	11111	\$1 P62 \$1 111 72,155 \$6 661 11 811		1, 6.6 1, 665 1, 465 1, 466 4, 416	: 37	1 418 1 548 4 4 4 4	1.01	1 19- 1 101 1 11 1 11-4 1 1 100		14 14 2**	1: 00 1: 00 1: 00 1: 00	1,896 16,836 7,266 1,466

TABLE 3-IG

Boungle He Tomic (Pill) F from High p to 0,10 p is boundle rom \$2.00 J d Paid form 19 Etq. He	F43 1900 R 190 190 190 190 100	,	7 5 0 (1990) (289) 1 195 1 195 1 1	n 12 * ⁹	291 (449) (14) (15) (15) (16)		2 46 - 1619 - 1619 - 1616 - 1616 - 1616 - 1616	N , 10 · 3	9 97 1999 75 16 199 1 9 15 1 9 15 1 9 15	,	F 46 1949 *8 24 16 18 6 17 1 11 1	se ^{∞3}	761 1997 1 67 1 16 10 15 6 6 46 1 15 7	i 18 ¹⁸
improgs im 1 minrogs	100		42	in	6 .	4 s 10 344	₫A IV:)7 g 10, 544	4.00	, . - ma	100	N 1	4.	10,000
1953-2806 1,1202-1,0030 1968-1958 1,0030 1,4706 1958-1250 1,0700-1,7211 1-68-2756 1,7210-1,212 1100-2200 1,212-1,313		*****		0. 0 117 10 011 00.700 100.111	17.00 17.00 17.00 10.00	0. 1 075 7 151 151:154 160:445	9. 1.41 7.10 17.00 95.00	8, 5,276 97,944 776,197 719,181				:	133	8. 9. 9. 13.104
######################################	11.17 11.13 47.47 11.14	964, 117 774, 989 784, 984 194, 981	87 - 55 97 - 56 91 - 91 93 - 24	**************************************	100 9 100 9 100 9 100 9	656 061 611,773 641 566 746,811	10 0 10 0 10 0 10 1	#/*, %% / #61, 167 #11, #85 #13, #67	\$.15 \$.35 \$.35 \$.35		15	10 679 1 719 10 600	19:33	119 119
2000-2005 3,9024-6,9075 P005-20-0 4,909-6,2751 2018-2019 5,907-6,2020 2018-2019 5,907-6,2305 2020-2025 5,007-6,2305	***	-	18 s 18 s 18 s 18 s 18 s	: 0 t 6 t : 0 t : 0 t	# :	*: :::::::::::::::::::::::::::::::::::	* 12	14: 1:000 1:170 1:170	: : : : :		•	1.		i
2923-2834 4,5941-5,5941 2014-2613 4,5245-4,5144 1215-2614 4,5145-1914 1045-2614 4,517-1914 2045-2614 4,604-4,6744	•	.	4: 4: 4: 11	*	#. 0. 0.29 1.67 1.15	6. 6. 156 7.116	1; # 1; # 1; # 1; # 1; #	1.114	**	45-44	18. 18. 1. 18.	‡:	•	1. 1.
7950-2855 (.gre, 1,560- 2855-2809 (1,664-1,550- 2865-2855 (1,615-1,622- 2605-2856 (1,623-1,622- 2676-2875 (1,623-1,619)		1.3	111	2 2 2 3 F	1.19 1.69 3.69 7.11	. 155 . 6 - 6 6 6 6 17 4 . 5 16	1:31 1:44 5:17 5:17 8:19	f: 1:35 1:858 1:457 1:468			#1 #1 #1 #1	6. 1. 1.		
4c 2000 5c4113 5c6672 \$100 2605 5c477 5c756 \$000 1000 5c776 5c756 \$000 1000 5c776 7c756 \$000 2605 5c776 \$000 2605 5c776	1.5	6,116 1,869 1,867 1,867 1,275	1 41 4.21 2.74 2.75 1.75	1 345 1,617 6 516 6,618 1,175	1, 67 1, 67 1, 13 1, 13 1, 14 1, 27	2 125 1, 261 1, 211 1, 211 1, 114	7,34 6,57 7,45 11,22 13,16	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	11. 14. 14.		*, : *, : *, : *,	¥, • • • •	•	• • • • • • • • • • • • • • • • • • •
#188-8175	4:37 4:47 1:42 1:44	1,344 2,10 1,10 1,10 1,10 1,10	4,24 4,14 3,41 4,41 7,4	1, 561 6, 165 6, 666 5, 763 6, 435	7,14 9,13 9,11 9,24 18,38	6,114 1,14 1,14 1,141 12,141	19,30 19,81 84,36 21,65 87,46	15. ef 1 15. ef 1 15. ef 1 17. 540 15. 574		•	•		•	# : * • : • : • :
#195-#15- 6,1465-8,8566 #180-#15- 6 965-8,856 #185-#16- 6,550-6,94# #185-#16- 6,570-8,884 #185-#15- 6,676-8,851#	138 138		0, 19 14, 27 19 46 15, 45	7,541 9,834 11,150 11,251 5,761	19,19 11,19 18,16 18,16 18,17	04.00 4.00 10.00 1	9,29 17,15 57,57 48,57 38,48		:	•	• 1		†. †. 	6. 6. 1.151 8.218 9.446
#158-7155 \$ \$374-8,666 #158-2166 \$ \$266-6,2266 £168-2168 \$ \$666-8,6168 £161-2168 \$ \$267-8,666 #14-218 \$ \$6628 \$ \$877		0.576 11.177 16.136 16.367 17.368	21,28 28,24 -8,51 (1,61 66,72	18.05 (1.56) 40.17 81.17 81.17	16.67 50.11 50.67 50.51 50.51	11, 14, 11, 14, 11, 14, 14, 14, 14, 14, 14, 17,	\$2,50 \$0,55 \$5,11 \$.51 \$0.55	11.173 11.173 11.173 11.173 11.173	***			1. 1. 1.	0, 50 0, 94 1, 65 1, 76	* 11/ * 21 * 171 * 144
2:75-2:56	10.12 10.12 10.13	#1,545 #6,776 #7,155 17,465	11.04 11.11 14.01 14.15 17.15	10 r 1 42.697 17.753 18.407 17.644	19,44 15,49 18,44 84.43	64.373 45.754 96.64 77.355 77.335	30.00	79.345 91.000 91.000 91.277 91.277	4.42 7.10 7.61 4.64	y bat 0.500 1.551 4.531 1.575	4.41 4.41 4.41	6.819 6.436 9.613 1.141	1.64 2.66 2.4 2.11	. ~4 1 /1 2, - /1 4. 333 1. 439
288-2895 (150 8185) 289-2818 (151 8186) 2818-2715 (151 1818) 2818-275 (151 1818) 2718-2829 (151 1818) 278-2829 (151 1818)	#2	10,210 17,010 18,017 18,017 11,101	79.91 74.99 74.14 94.89	\$11' \$11' \$11 \$11' '7.844 15.75'	10.00 10.00 10.00 10.00	00 (0) 00,370 00,811 01,511 01,511	10, 11 10, 61 10, 64 11, 64	7. 751 7.771 7.771	6.43 6.46 1.46 1.15	1 636 2.657 1.529 1.509 1.609	7.18 7.18 7.18	. 554 . 547 . 547 . 548	1.44 4.69 1.41 5.41	3 347 3 447 4 446 2 443 2 443
#### #### ############################	11:2	12 884 12 301 17 304 17 304 17 306	64 61 64 61 67 64 61 73 61 73	19,715 19,719 91,199 81,191 10,191	69.17 89.14 86.16 86.94 81.81	01,011 et.100 et.100 et.100 et.100	100 69 100 60 100 60 100 60	M. 111 M. 111 M. 111 M. 111 M. 111	8 - 5 8 - 64 8 - 62 3 - 14 1 - 67	. 80. 2.100 2.000 2.113 3.413	7.2	1200	1.50 1.51 1.61 1.51	6 - 596 7 - 516 6 - 766 7 - 596 18 - 766
#### #### 1, mean 1, and ###################################	7011 1111 1111	11. 613 11. 65 11. 65 11. 15.	89,54 89 (1) 81 (3) 81 (3) 81 (3)	.4.144 91.941 94.941 27.144	100 m 100 m 100 m 100 m	11 11 11 11 11 11 11 11 11 11 11 11 11	177 - 87 297, 44 - 97 - 98 - 98 - 48 165 - 98	M. 121 M. 121 M. 121 M. 121 M. 121	1, 17 1, 18 1, 18 1, 18 1, 18	1, 354 1, 5+1 1, 541 1, 141 1, 141	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 / 54 6 : 754 7 : 855 1 : 861 7 : 805	18.62 11.54 16.68 15.66	17,454 14, 7, 16, 444 16, 15
pith day — 1, 1 1, 1000 ords (25% — 1, 100 — 1, 150 240 10 — 1, 100 — 1, 150 25% april — 1, 100 — 1, 151 25% april — 1, 117 — 106 25% april — 1, 117 — 106		10 101 10 101 10 101 10 101 10 101	67.59 68.46 61.21 96.67	09.766 07.599 07.300 07.553	10- 11 1811 1 1841 1 1961 1 1971 84	****	14 H 14 H 14 H 14 H		1 pt 1 m 1.3 m 1 t/ 1 t/	1 137 1 111 1 1 101 1 101 1 101 1 101	*: 47 * : 3 * : 4 * : 5 * : 5	1: \$15 1: \$1 6: 141 6: 1-1 6: 1-1	19.59 19.59 19.59 9.59	19 - P15 54 - 54 1 54 - 54 1 54 - 54 1
200 200 : serve, the general serve and serve a	10 H	N 144 Op 001 D 147 N 171	\$ 17 \$ 7 \$ 7 \$ 17	MG 174 MG 171 MG 171 MG 171 MG 171	M 17 M 17 M 17 M 17	6, 962 68, 791 69 600 69 600 87, 180	100 . 51 100 . 54 101 . 64 101 . 64 101 . 60	11.11	1 54 1 21 1 21 1 21 1 21	1 116 1 116 1 147 1 15 1 15	#1.60 #1.30 #1.46 #1.11	0 0 Mg 0 255 0 826 0 861 0 155	4, 11 - 14 6, 4 - 17 - 21	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Ent pasa 3 mm 4.2500 page 2500 to pr 6 0.2600 page 2500 to page 5 0.250		10 171 20 100 10 100 10 100 10 100 10 100 10 100	80 64 80 67 11 67 12 67 13 68	#6. 650 #6. 850 10. 81 #6. 143 #6. 743	90 c) - 60 c kr - 90 c kr - 90 c kr - 90 c kr		64 4 74 64 61 92 14 94	61 - 118 61 - 11 - 61 - 200 61 - 401 61 - 401	\$1.50 \$1.50 \$1.60 \$1.63 \$1.63	1, 578 1, 655 1, 1 1, 586 1, 1, 66			-1.57 -6.06 -7.05 -7.15	19 9 9 10 000 10 100 15 000 10 85
2562 2200 1,531 1 5 546 1 5 566 2 5 566 2 5 566 1 5 566 1 5 566 1 5 566 2 566 2	11 5		19 . 3 · 1 11 . 1 · 1 10 . 1 · 1 10 . 1 · 1	11 11 11 11 11 11 11 11 11 11 11 11 11	# 13 # 13 # 13	15 551 95 361 96 371 97 341 97 341	100 e4 100 e4 101 14 101 14	h1.04.0 M1.74.1 AL.644 M1.46.1	1. p1 1. 14 1. mi 1. mi	6 0 16 6 2 11 6 0 M 2 9 9 5 7 3 4 9	6 61 6,71 1 19 6:66	1, 141 1 125 1 126 1 120 1 120 1 120	19743 1979 1979 1979 1974	17.000 6.000 17.166 8.267
27% 2500			11 14 14 11 14 11 14 14 14 14 14 14	6 1. () 56,000 10,560 01,60	69 . ps 18 . ss 1 . ss 1 . ss	10,101 10,101 10,101 10,101 10,101	00, 67 61,000 71 60 1 61 1 61	11.111 11.111 11.111		t lis. help 1-8 1-86 1-850	2 Mg 2 Mg 2 Mg 2 Mg 4 Mg 2 Cd	1111	1 11 1 11 1 11 1 11	5 54 6 5: 16; 6 656 1:566 6 965

٦	Δ		ı	F	3	- 1	1	Н	١
	-	\mathbf{D}	L	L	J				ı

Bampie He Temp. [*M P mm Hg) p (CO)/* p (atmus rr p a red ou rig. No	n etpi	F96 1600 Mt 66 16 16 25 8 = 1 66 1	9.1	F4) 194- ⁴ X 191 14 19 93 8 4 81 5 3-7	- 1	7 62 1800 ⁶ 50 161 16 - 85 164 - 1 1 - 8 3 - 7		F41 400°7 400°7 400°4 400°4 		F54 1500 FR 1556 16 8 FS 621 6 16 21 7 3 - 7	1	Fex :500°M 14 1 44 1 49 4 1 49 1 49		7 14 1 1000 K 47 3 7 4% 6 64 6 1 11. 2 1 + 0	ıe·¹
	rval Mirtsda	Z=	N .	€ × 190	N s 10 our	Z 4	N =	/en	N s ,g, seq	E 4	N s 10.000	Z 4	N <u>.</u> 10, 944	K	10.000
1950-4960 2050-2150 2150-2150 2150-2150	1,1204-1,0006 1,000-0,0707 1,0700-0,7010 1,0700-0,017 -,017-1,313	1:33	\$; \$; \$; \$;	1 0. 0.00 1.07 0.11	0, 9,917 13,913 71,140	0 0 4 14 1.33 (1 64	3 0. 1.007 20 040 110.0(2	0. 0. 0.15 0.15 17.05	0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0	0 1 44 1 40 1 18	0. 0. 12.117 10.030 304.300 FFA.003	8. 8. 8. 8. 9.49	0. 0. 0. 0. 0. 0. 0. 11.100		8: 6: 6: 7:31.8 81:468
\$170-1400 \$100-5125 \$190-5160	6,56;,-1,6066 6,666-6,5676 6,5678-6,5715 6,5715-6,7667	15,66 27,53 25,62 11,62	112,001 201,021 204,711 110,120	45.35	\$11,0.2 \$65.821 \$21,160	79.44	407.000 460-300 171.000	\$1.51 \$1.75	818.218 860.799 361.308	69.61 69.22	647,735 +00,915 129,971	1.07	27.160 16,835 22.462	1.41 1.41	19.631
2010-2010 2011-2010 2011-2010 2011-2010 2011-2010	0,3/80-0,000i 0,000i-0,6100 0,000i-0,6100 0,000i-0,000 0,000 0,000	*****	-0. -0. -0. -0.	-0. -u. -3. -0.	-0. -0. -0. -0.	.0. .0. .0	-0. -0. -0. 3. 0.0	-9. -0. 3. 0.11 0.45	-0. -0. 0. 0.090 0.077	0,11 0,19 0.40 0.40 2.94	0.00 0.121 0.000 0.702 0.000	-8, -8, -2, -9,	.0; -0; -0; -0; -0;	-0. -0. -0. -0.	0. 0. 0. -0.
1017-1-10c 1010-1017 1007-1010 1000-1007 1017-1000	a.8171-a.6877 a.6877-a.7343 a.7543-a.7547 a.7547-a.7543 a.7785-a.7618	4.	-9, -9, -9, -9,	.0. .), .0, .0,	1.017	0.36 0.67 0.67 0.60 1.00	0.115 0.108 0.549 0.747 0.745	1,17 1,19 1,00 1,00	0,450 1,105 1,105 1,925	1,46 1,67 2,45 2,10 3,41	2.047 2.047 2.331 2.000	-0. -0. -0.	.6. .0. .0.	-0: -0: -0:	• 6. • 6. • 5.
2100-2125 8100-2120 2110-2110 2110-2120 2120-2125	u, foly-u, fydo u, fydo-u, fyfi u, fyfy-u, fydi u, fyfi-u, fife u, fifo-u, fely	11:	-0. -0. 0. 0.021 0.100	u 17 u 19 u 40 u 62 u 61	0 161 0 137 0 113 0 113 0 113 0 176	1,30 1,49 1,69 1,91 2,34	1,896 1,276 1,661 1,665 1,716	7, 11 7, 67 1, 17 1, 13	1.765 2.366 2.438 3 1.45	1.85 4.11 4.15 1.16 7.17	1.207 3.0 4.221 5.164 6.233	-0. -0. -0.	• • • • • • • • • • • • • • • • • • •	.0. .0. .0. .1.	-0. -0. -0. -0. -1.
\$189-\$190 \$190-\$190 \$190-\$100	0.7010-0.0708 0.000-0.0038 0.0050-0.0737 0.0737-0.0038 0.0070-0.0017	8.40 9,78 9.60 1,10	8.892 8.882 9.811 1.822 1.252	1, 14 1, 14 1, 17 1, 17 1, 16	1 067 1 517 2 136 1 156 1 07-	B 2 2 2 3	2 MB 1 67 6 36 6 77 1 MB	0.10 0.10 7.07 0.00 19.17	4.614 4.616 4.444 7.777 4.463	(0 %) (0 %) (1 10 (4 40 (4 40	7, 104 9 344 11 416 14 216 17 046	-0: -0: -0:	•	• • • • • • • • • • • • • • • • • • • •	-0. -0. -0. -0.
7130-2155 2153-2160 2168-2163 216 -2170 2170-2173	a, a 5 2 - a, a 4 8 a a, a 5 0 - a, 0 2 0 a a, a 2 0 - a, a 1 0 9 a, a 1 2 - a, a 6 0 1 a, a 2 2 1 - a, 3 4 7 7	1,70 1,06 2,71 2,14 1,76	1.469 1.697 1.926 2.296 2.296	1,07 0,10 0,40 1,11 4,77	1, 14.0 1, 57.6 4, 10.3 4, 87.6 5, 87.7	2 55 6 86 13 16 11 81 11 79	4 40 7 400 8 700 14 328 11 848	17,74 15,24 17,74 21,44 20,41	11,61, 10,150 10,350 10,670 21,100	10 1 11 12 12 13 61 13	10 1446 23 817 37 861 11 811 14 811 15 811	-0. -0. -7.	-6. -6. -9. -6.	-3. -6. -6. 6.61	0, 0, 0, 0,304
2:54-2100 2:64-210: 2:05-2:00 2:54 2:05 2:05-2200	4, 1017-4 417 4, 5072-4, 9797 4, 9767-4, 1007 4, 1007-4, 1118 4, 1110-4, 1118	1.00 9.70 9.33 9.31 7.35	1.461 4,128 4,811 1,166 8,166	0,01 0,08 11.45 13.00 15,20	6.768 8.768 9.791 11.615	15.76 16.11 21.65 25.69 27.61	13.696 15.793 10.610 21.691 24.133	29,14 52,14 56,48 61,68 66,27	70,085 20,215 12,200 50,101 02,601	17.24 11.65 10.76 61.61	\$1, 178 \$1, 178 \$6, \$63 \$1, 735	-9. -9. -9. -2. -2.	-0. -0. -0. -1. -1.	0.30 4.17 2.78 6.79	0,117 2,500 0,603 7,667
2204-2261 2210-2211 2210-2211 2210-2211	0, \$855-6, 5361 6, 5361-6, 5269 8, 5260-6, 5137 8, 5167-6, 5865 6, 5865-8, 8849	8,67 18,10 11,61 12,62 19,87	2,711 6,616 18,626 11,867 13,293	17, h 17, h 17, h 27, 61 27, 23	10,176 17,166 10,511 21,617 21,617	11.10 12.76 16.11 17.11	12,161 10,007 13,761 17,314 18,815	10.94 48.99 41.30 50.77	46,741 48,177 33,442 47,427 64,307	15,77 64,51 66,67 64,71 64,71	79.331 76.374 77.313 79.744	2,25 2,67 3,69 7,29 1,67	0.280 9.490 2.117 1.640 1.293	1.51 1.63 1.56 2.11	1.230 1.230 1.220 2.300
\$\$4.511.5 \$\$4.55 \$\$10.5\$ \$\$\$4.51	0,0000-0,000 0,000-0,0701 0,0705-0,000 0,0005-0,000 0,0005-0,000	15.66 17.10 16.73 20.80 21.01	(1, 271 15, 151 16, 516 17, 958 19, 295	29.17 19.65 19.62 20.15 10.67	20,392 20,020 11,271 23,723 30,177	14,31 13,41 17,41 18,41 14,31	46,916 46,976 49,916 91,486 98,917	71.37 27.33 81.27 81.28	63.168 66.799 71.756 75.687 71.838	10.11 10.11 17.13 10.11	01.500 01.210 01.110 01.110	1.00	1,007 1,000 1,000 1,700	1.13 1.45 1.66 1.11	1,101 1,000 1,010 1,017
1114-1137 1102-3114 1104-3124 1126-3137	0.000-0.0146 0.0356-0.0146 0.0166-0.0134 0.0166-0.0151 0.0015-0.0138	11.50 21.40 31.51 31.50 21.50	#6, 881 ##. 611 ##. 55- ##, 667 #6, 965	11,10 17,10 17,10 17,10	10.010 12.000 11.010 12.010	90.01 10.03 11.41	10,000 04,010 04,751 01,-62 11,62	64.64 69.71 61.44 61.67	76, 511 76, 661 61, 811 62, 364 61 533	10.10 10.10 10.10 10.10 10.10	\$7,042 60,100 60,17 64,767	1,05	2,178 2,444 3,744 3,444	1.81 1.11 1.60 0.10	1.135 1.135 1.001 4.013
1702 - 3714 1304 - 524 1107 - 5301 1200 - 5301 1512 - 3306	a, 5046-a, 1948 a, 3046-a, 1946 a, 5764-a, 1048 a, 5068-a, 7274 a, 2572-a, 5a78	10.78 10.65 10.66 10.66	30.013 30.967 30.303	10, 10 10, 10 11, 20 11, 61	11,11 11,11 11,10 11,10 11,10 11,10	79.44 74.44 74.47 74.47	04,162 04,474 04,594 07,159 07,169	11.07 11.07 11.0 11.0 11.0	41.022 04.002 04.007 01.072	194.64 194.64 54.64 194.64	61.371 61.176 69.579 69.561	133	1,111 1,001 1,100 1,101	1,32 1,11 1,25 1,05	6.136 6.136 6.136 1.119
# 100 0 - # 100 0 # 100 0 - 2 1 - 2 # 2 2 0 - # 2 2 2 # 2 1 0 - # 2 2 2 2 # 2 2 2 2 2 2 2 2 2 2 2 2 2 2	a, pare-a, 190a a, paga-a, proc a, proc-a, proc a, proc-a, proc a, proc-a, per	11.01 10.11 10.11 10.11	27,161 27,221 26,091	93.65 92.74 92.75 92.75 92.71	43,494 44,428 47,481 46,731	74.44 74.44 74.44 74.44	61.143	11.55 14.75 14.75 11.73 14.15	#3, 944 #4, 854 #4, 875 #4, 187 #5, 276	194, 94 194, 94 194, 94 194, 84	99,761 99,061 94,967 96,969	134	1, 144 1, 576 1, 647 1, 644	1,66 1,62 1,66 6,61	7.111 7.426 7.846 7.846 7.866
\$14 6 - 1 1 1 6 1 2 5 4 5 1 5 1 2 2 5 4 5 1 5 1 2 5 6 7 - 1 2 5 1 2 5 6 6 - 1 2 5 1	a. 1011-a. 2010 a. 2010-a. 1027 a. 2027-a. 2754 a. 2110-a. 2044 b. 2144-a. 2555	10.55 10.55 10.56 10.56	j 2, 511 24, 444	\$8,65 \$8,00 \$1,00 \$1,00 \$1,01	17,740 14,004 19,01	10.11 10.11 10.20 10.20	\$4.444 \$1.444 \$1.144	#	\$0.01 90.00 90.00 90.00 90.00	114.11 114.11 114.11 114.11	14.11 44.341 51.141	1.00	1, 100 1, 110 1, 111 1, 111 1, 110	9.00 9.00 7.00	1,83; 2,993 8,196 1,179
9949-9644 9445-944 9445-1444 9445-579	5,2561-4,2495 4,2469,2515 4,2464,2564 4,226-4,2164 4,1164-4,2165	24.41 25.16 21.06	1 19.874	10,11 01,01 00,10 11,11 10,11	14 PGG 12 GGT 84 GGT 25 000	67,51 67,51 61,66 55,61	61,164 51,664 -1,64 -6,77	\$1.88 \$1.98 \$1.99 \$1.99	07.407 01.005 77.000 73.761 07.374	17.00	*0.919 60.811	1, 10 1, 15 1, 17 1, 29	6,868 6,963 6,771 8,771	9.41 1.43 9.49 9.41	1,687 6,764 1,781 6,714
\$ 40 0 \$0 14 \$ 500 1 \$ 501 \$ 500 1 \$ 501 \$ 400 1 \$ 500 \$ \$ 50 0 1 \$ 500	6. 998.6.1991 6. 9.1991-6.1796	10 , 30 9 , 94 5 , 94 3 , 57 6 , 6	7,864 5 4,636 5 3,244	11.54 11.55 11.56 11.66	16,944 6,955 6,967	\$0.00 \$1.00 10.01 10.11	1 4 30 9	11.01	10,715 10,451 10,400 20,251 1,151	11.00 11.10 14.10	90,181 10 181		1, 161 1, 161 1, 164 1, 166	133	1,000

TABLE 3-11

Bamers via Tobby, fret of fictor light of fictor on Agri glaters com Agri grow on factor fight by factor?	\$ 40 \$	**************************************	字 為 哲	FAU FAU	FAI 14 R 14 BH 14 R 17 4 M 14 4 BH 14 1 17 7 1 7 1
imprest em ^{oj} imprest	E# N = 180 18.60#	iun iu, 660	É* R. 188 18:898	E★ ¼★ 188 18;846	Ē× N; 188 :8; 8n6
1430-3000 1,126-3,0480 141-24-0 1,000-3-3-6740 1-3-6-7-70 1,54-0-1-70-6 1-6-2-1-0 1,74-0-1-70-6 1-6-2-1-0 1,74-0-1-3-0 1-6-2-1-0 1,74-0-3-1-3-0 1-6-2-1-0 1,74-0-3-1-3-0 1-6-2-1-7-9-0 1,00-3-1-3-1-3-1-1-3-1-1-3-1-1-3-1-1-3-1-1-3-1-1-3-1-1-3-1-1-3-1-1-3-1-1-3	di di di di di di di di di di di di di di	#: #: #: #: #: #: #:## #:\$## \$:## #8:94 !!##	#: #: #: #: #: #: #:f# 4:f#! #:f# 9:##!	0: 0: 0: 0: 0:007 1:00 0:007 1:10 10:109 13:30 110:200	0: 0: 0: 0: 0:03 0:356 3:54 4k:464 24:47 217:161
######################################	9:88 91:111 12:89 114:812 12:84 12:845 12:84 5m:158		78:31 /40:71K 18:31 119:597 50:15 19:148 27:15 148:34	\$4:46 \$46:469 fr:63 642:675 fb:61 483:641 48:46 483:761	08:28 801:387 97:47 822:400 94:74 853:462 67:40 417:754
#89t-1'44	-0: -0: -0: -0: -0: -0: -0: -0: -0: -0:	-6: -6: -6: -6: -4: -6: -6: -6:	- 0: - 0: - 0: - 0: - 0: - 0: - 0: - 0: - 0: - 0:	- 8 - 18 - 18 - 18 - 18 - 18 - 18 - 18	-6: -9: -9: -6: -6: -6: -6: -6: -6: -6: -6: -6: -6
1874-2884	- 8	-0: -0: -0: -0: -0: -0: -0: -0: -0: -0:	- H	-9: -8: -6: :8: -5: -8: -6: -8: -6: -8: -6:	0:14 0:010 0:84 0:150 1:04 0:815 1:10 1:000 1:15 1:160
# 184 - 4145		- Hr	- H	0:440 0:440 0:440 0:440 0:440 0:440 0:440 0:440	1.48 1.594 1.47 1.904 2.47 1.804 2.47 2.684 2.47 2.408
# 1 4 5 7 1 4 9 4 1 6 4 4 4 1 6 7 4 1 6 7 4	-0: -0: -0: -0: -0: -0: -0: -0: -0: -0:	######################################	6:14 8:014 1:17 8:44 1:14 1:45 1:14 1:44 1:14 1:44 1:46 1:46	1200 1200 1200 1200 1200 1200 1200 1200 1200 1200 1200 1200 1200	9189 9188 9197 9188 9188 9189 9189 9189 9189 9189
4144 4144 m. Pilaten ant. 4144 4144 m. Pilaten ant. 4145 4144 m. Pilaten ant. 4146 4144 m. Pilaten ant. 4146 4144 m. Pilaten ant.	11.61 B:41 11.61 B:41 11.61 B:41	1.60	#104 #1348 4194 #1046 4191 4146 4201 4146 4201 4146		11.46 U.568 14.50 11.466 14.60 12.75 14.60 1.466 11.76 14.466
\$189:-\$189	1:40 1:400 1:40 1:407 1:40 1:407 1:40 1:40	#:## #:### #:## #:### #:## #:### #:## #:### #:## #:##	6:00 9:799 f:40 0:479 7:40 f:479 11:41 7:171 14:41 18:44	41 4 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
######################################	日本 (日本) 日	6.15 5.448 f.164 6.157 f.24 7.854 f.15 7.658 f.17 14.888	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	# 1	61:88 4:045 40:63 40:638 48:63 90:474 40:63 54:954 60:44 48:874
त्त्रेषु तृत्रेष्ठा च्याप्तात्रः च्याप्ताव्यः वृत्रेष्ठा वृत्रेष्ठा च्याप्ताव्यः व्याप्ताव्यः वृत्रेष्ठा च्याप्ताव्यः व्याप्ताव्यः वृत्रेष्ठा च्याप्ताव्यः व्याप्ताव्यः वृत्रेष्ठा च्याप्ताव्यः च्यापत्रेष्ठाः च्यापत्रेष्टाः च्यापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्टाः चयापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्यः चयापत्रेष्यः चयापत्रेष्ठाः चयापत्रेष्ठाः चयापत्रेष्टाः चयापत्रेष्यः चयापत्रेष्टाः चयापत्रेष्टाः चयापत्रेष्यः चयापत्रेष्यः चयापत्रेष्यः चयापत्रेष्यः चयापत्यः चयापत्रेष्यः चयापत्रेष्यः चयापत्रेष्यः चयापत्रेष्यः चयापत्रेष्	N : 10 to	1 4: 44	#7:44 PM HFF PV:#F PA:MFF BV:AH PM:FRF BV:#W 4 184 AF:M6 40:M9	कर्गास्त्रं सहात्रकार क्षात्रक्ष्णं सकार्वेशक क्षात्रक्षणं सकार्वेशक क्षात्रकारं सहार्वेशक क्षात्रकारं स्थान	find of fas fand on ori fand fant fand fant frie fant fan ar
त्रिकेत्र विशेष्ट क्षेत्र प्रश्नित्र विशेष्ट्र इत्त्रीत वृत्तेत्र क्षेत्र क्षेत्र विशेष्ट्र इत्त्रीत वृत्तेत्र क्षात्र विशेष्ट्र विशेष्ट्र इत्तरिक्ष वृत्तेत्र क्षात्र कृष्ट्र विशेष्ट्र	16.84 V.648 11.64 16.555 17.65 11.46V 12.11 11.484	pican inches prist proper pacit picapa pacit picapa pacit picapa pacit picapa pacit picapa	by: dy 442 Auf uf: 14	ntith tithe ntite and proper fried and proper fried ntithe flied ntithe	##- 16
## ## ## ## ## ## ## ## ## ## ## ## ##	१६/१४ १४/१४४ १६/१४ १४/१४५ १४/१५ १४/१४५ १४/१४ १५/१४५ १४/१४ १४/१४५ १४/१४ १४/१४५	Priva paida friad paida friad friada friad friada friad friada	##:## ##:## ##:## ##:## ##:## ##:### ##:## ##:###	faire africa faire acriti faire africa faire africal	11,47
वृक्षस्य मुद्देशस्य प्रदेशस्य प्रदेशस्य स्ट्रिक्ट्स मुद्देशस्य स्ट्रिकेट स्ट्रा १, १, १५ स्ट्रा स्ट्रा स्ट्रिकेट मुद्देशस्य स्ट्रिकेट स्ट्रा स्ट्रिकेट स्ट्रा स्ट्रिकेट मुद्देशस्य स्ट्रिकेट स्ट्रा स्ट्रिकेट स्ट्रा स्ट्रा स्ट्रा स्ट्रा स्ट्रा स्ट्रा स्ट्र	\$4:84 \$4:55 \$4:75 \$4:55 \$4:45 \$5:44 \$5:45 \$5:44 \$5:45 \$4:45 \$5:45 \$4:45 \$5:45 \$6:45 \$5:45	##16# 4#1### ##2## ##2### ##2## ##2### ##2## ##1### ##16# ##1### ##16# ##1###	स्तः देशः स्तः होतेन प्रशः हेतः स्तः श्रिकः वसः इतः स्तः हेत्रः वसः हो। स्पः स्तः वार्थाः स्तः वेत्रः	fa: 11 a f. 44a fa: 14 a f. 41a fa: 15 a f. 61a fa: 15 a f. 61a fa: 14 a f. 47a fa fa a f. 47a	#4;## #4;## #4;## #4;### #4;## #4;## #4;## #4;##
हे ने क्षेत्र के देवेश के दुवेश के कर कर के हैं कि है के कि के कर कर के कि कर कर के कि कर कर के कि कर कर के कि के कि कर के कि	1 1344 14 2 7 8 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	#Y:11 + 61:44 C #Y:12 # 61:46 C #Y:14 #6:46 C #Y:14 #6:44 C #Y:44 #6:44 C	111,114 NA.188 3-144 NA.188 111,14 NA.188 111,14 NA.188 111,15 NA.188 111,15 NA.188		#4:44 84:44 #4:45 44:759 #4:64 84:87 #4:44 84:44 #4:25 84:47
वेपाय विश्वतं स्टूब्येच स्टूब्येच वेपाय विश्वतं स्टूब्येच स्टूब्येच वेपाय वेपाय स्टूब्येच वेपाय वेपाय स्टूब्येच वेपाय वेपाय स्टूब्येच वेपाय वेपाय स्टूब्येच	14.244 (4.49) 16.39 (1.444 16.39 (1.49) 2.44 (1.49)	हर्तः केल हर्षः हेर्स्स हर्ते चर्तः हर्ग्यकेषः हर्ग्यक्तः हम्यकेषः हर्ग्यकेषः हर्ग्यकेषः हर्ग्यकेषः	##: 45 # 1:16 # 1 # 1:16 # 1 # 1 # 1 # 1 # 1 # 1 # 1 # 1 # 1 #	fr. sh ha. ber filled ha. fan ha. ba. ba. hi. en ha. fan he. en ha. fan he. en ha. fan	10,17 87,405 17,00 80,100 81,00 81,100 84,07 70 800 81,01 71,574
# # # # # # # # # # # # # # # # # # #	\$1.60 \$1.601 \$1.60 \$1.50 \$1.00 \$1.50 \$1.00 \$1.00 \$1.00 \$1.00 \$1.0	10,28 21 4-9 1,48 4,844 2,56 4,544 4,57 1,646 1,47 1,446 1,48 1,486	64,45 44,844 19,44 17,444 17,14 11,448 9 44 41,746 9,54 2,445	\$1,57 \$5,744 \$1,48 \$1,484 \$4,71 \$4,454 \$1,51 \$19.558 \$1,44 \$1,740	75,95 BF MMP BB 98 98,777 BB,07 BF,077 68,96 87,698 58,96 14,779

	ą.	, ii	155 1666			44444	+++++	+++++	11517 274	Canta 111111				\$55.53 \$55.53
	elitial	ü	41533	12337		****		11114				11173		19333
	~	, 1	4447 <u>y</u> 8			44444	11414	44444	44444	44444	41111	12321	11111	11551
	riessi.		ន្ទន្ធក្	TYTAN	斯爾拉爾 和尼拉	†* †	+++++	44444	1444	44444			35235	
	7,	. 1	학교학생 기		***	44444	44444	44444	44444	77777		11111	<u>19931</u>	ASKAR
	กลี้และเรื่อน กลังสมสัง	.; A	4774 8	\$3595 ********	海路 · · ·	4444	44444	41444	****	11111	33323	<u> </u>	15381	39583
		. 1	11117	in the	242 4624	44444	+++++	44444	11111	44444	44444	44444	14411	14141
	aneshan	41	สลสลสี	ttitt	}33. :	नेक्नेक्ने	11111	####	****	44644	#####	र त े हैं है है	++1115	11111
3-2A	1		777 9 22		1027	1 1441	14444	11111	11111	######################################		*****	\$5733 11133	iiiii
	ekatika:	13	dita	1141	ŞŞ.	ijiri.	4:Y13	14174			3374	33113	Mari	
LE	*	.1	42.02.7 42.02.7	eriji.		41144	11111	 	44444	44444	11111		Mi	НН
TABLE	ส์ผลังม	.5 R	222. ÌŽ	10711 1224	135. 135.	44-14	11/11	William	277	*****	.::354	53 1	HMi	15555
•	, ī,	;		17237	3 11	14411	ļ	\$2. 	щ	iiiii	iiiii	ЩЦ	2910	59584
	<u>ीर्धकेंद्र</u>	.:1	4 d n dy	20000 13544	};};	17474	(())	13-11	*****	!!!!!	11111	14113	MARK	14031
	. 1	; !	aaaa i			14430	11411	19949	34413	नं केले उ ने	44444	4	: 1311 : 1	31011
	ોલોંડ ———	4:	2122	1445		17.75	213	(4340	र सुक्री -	337.3	[3 **]	1000		1111
		;;	e 20 . \$			12124	3431	1444	व्यवस्	\$3\$ \$ \$	aş es	ंक्रे∳हें।	11112	
	Aidis ———	41	vac iš	Mi.		14,104	17 4 44		gart.	74044	1000	\$ \$ \$ \$ \$ o	312	555
	\$ 6	!	1000					.28		* \$45 ****** ****** *****				
	iii.	· '.		, 4: 1:11:	13 st 13 st	3325 · 3325 ·	30.31 30.33			: :: : : !t::: !	din Min	enn enn	991 988	

	.i	5555	HH.	m	11411			15472 11111	199		!!!!!		1541	##### #####		5575.
_	; ;;t	11999	13331		27512	47757	31454	1111	76512	****	HW	15015	##### #####	mi	15774 55881	31111
-	.!	1111	17315	1853	2335	13455	11115	1155	11618	1133	19344	22675	15653	1999		!!!!!
	: 31	53535	11111	44463	11.55			HELL	#1352 12888	35335	M	17511	# # # # # # # # # # # # # # # # # #	m	1135	2333
		11011	7515	11:11		11111	5335	48453		1133	11111				HH:	!!!!!
	71	54834 11124	15155	3144	19135	*****	11115	11115	11151	10101	111.2		1991	231	17715	17531
	; ; <u></u>	11111		33155	1995		311		1132	11115		HEH	1511	11111	1133	53332
_	11	55753	14451	1121	mii	11113	33433	mi	53355	11315	iriii	11111	11115		}1113 3	נוננ
3-2A (CONTINUED)	.! :	15345	1011	110		1363 1113 1113		491	14111		Hen Uiti	H	Hill	65395		1911.
8	**	1151		iiii	iii.	1111	Hill	3331.	1345	11111	31311	m		1746	1111	\$123.
2A ((, : !	1155	HH		!!!!!				1335	Hij	11111			nii Wii		11515
_	41	35333	11311		Hill	12114	lilli	iiii	31666	M	11111	\$\$555	51131	[][]	1111	11111
TABLE		<u> </u>	533	拐댉	1111	33111			15615		1110		11117		1151	1315.
F.	41	33533	74551	31.565	1111	11111	17,55	1775	Hera Jeets	1,127	iill:	1111	34141	1111		
														22	摄	
	-11		15311										1985	11111	11311	
			15111							13711			11111	14444	H	-4444
-	41		11411			1115		11113		1555			11111	1111	Miii	
	1			4			11111		(1))) (10))		***					
j		11111	His	fifil	\$2145	1911	ma	11111	11111	11111	11155	DH.	H		HHE	tilli

	î.		֓֞֞֞֞֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓	5255		3355	11113	5555	1247		53333			11111
	fa il e?	31	,155g			12011	15555	77577	11111	35535	55513		וְנְוּנְנָ	raera Signi
		. ž	1112		11173 220	44444	14444	1111 <u>3</u>		43513	21222	15311	15955	
	e leli si	,31	11321	1222	1111	44444	11111	1441	53555	11553	11111	\$\$\$\$\$	19553	
		4	EBP		1164	+++++	44444	E I	18141	11111	7513A	11111		
	र्मात्री ———	٦ ¹	135	13331	Įį.	44444	44444	, , , , , ,	35534	<u> </u>	RENTE	12865	19144	19935
	. 1	. 1	1111	11221		44444	4444	, 447 (111)	HH					
	elatii:	31		11515	1170	44444	*****	p. 335	11111	11111	14511	11111	15111	1354¢
		:	10.122	illian.		44444	44444	44444	44444	44422		14111		11355
	र्गात्स	.51	2235	3531)	3552	4444	44444	44444	44444	356	11111	33313		11555
		. 1	2.422		1111	44444	11111	11144	44111	47.734	13333	33133		11111
TAE	alitita	41	20223	3333		44444	14144	44444	11111	44434	13333	31333	19755	33368
		. !	1111;			44444	41444	44444	44444	44444	44444	****	117777 22	
	dilli:	31	iiiii	15311	553.	44444	44444	44444	44144	44444	14141	4444	93445	1935
		:	1212	Fill.	1132	वस १५२	न्त्रस्	44444	44444	44444	44444	44444	أأدب	
	Artic	71	1111	11311	!!! .	44444	र्वत्र्	44144	44444	44344	44444	न्द्रन्द	444.55	35465
	فرير	.!	4444	1634	H.	44414	14114	44 4 4	44444	• • • • • •	4444	44444	44444	44444
	र्मार्डिङ ——	41	2222	13115	1512	रेड रेड र	filifi	11111	4444	47444	44444	44444	7 4 444	49992
	i,	, 1				2 4 7 4 2 2 4 7 4 2 2 4 2 4 2 4 4 2 4 2								
	能	1,		11111		22173 22173 22173 23223	3514	\$1 5 55 \$ 535 5	\$ 6 6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	11011	1443		erere Resid	

	; <u>;</u>	11111	55556			11115	13111		*****			11111	11171	****		
	e ↓r	11221	32235	1533	Silving Filling	****	43254 22222			*****	11621	acaea acaea	Mil	1000		19655
-		11555			27453 21262			41161				15784				5174 7233.:
	i: Qi	\$2555 11111	****	Sist.	4044	261.	19835	4:11:			1611;		11111	#2255 #2255		3111.
		35355	1111	11625	35335	1717	E!!!!		11115	17:17	48285 42242			16278		
	ن	53533	1151	34333	1022	53333	1111	11313	1333 7	*****		1215E 1215E	A SECTION	11111	14335	13352
•		53353	1995	11373	5511	#3# <u>55</u>	\$5335	11111	18555	1447	NEW E			11115	15353	atez Madau
	f. M	35555	35955	11131	19915	11111	11111	11155			141#: 35775	!!)!!			<u> </u>	1511.
₹ 2	_; <u>;</u>	35535		1555	#245# 2345#	\$2551 22523		11535		12353	11111	#####	555	151ff	35535	23533 175
CONTINUE	; 31	33555	34543	#3555 13555	1833	37555	53455	33333	10487	17117	iiiii	15311	iiiii	!!!!!	iiii	55522
		3222	35555	33533	1211	1111	15177	Mill		Mail.	# \$ #1 \$	1551		3313	5555 <u>5</u>	11111 f:
3-2B		3555	33227	555	3333	1995	1311.	33333	3445	31.155 31.155	11111	##### #####		1115	<u> </u>	Mada
ABLE		34553	F#255		53535	55313	55333	13151	36553	\$3838 33333	5533 3	51515	55555	15515		61
_) -	59355	55555	7151;	15311	53334	Jilli	11151	53533	3535	11111	iiiii	11551	15553	iiiii	33442
-	. !	15115	1955	11111	11115	13151	14134	35553			31314	15151	12723	13151	18135	155
	.; .;	15551	11953	35753	19353	33535	11111	ifffé	j95 <u>55</u>	55555	15111	****	714.1 24618	*4*64	32335	351
	<u>;;</u>	13115	19744	13331	122 II	1231	53545	\$4 5 \$	\ <u>}\$\$</u> \$!!!!!	1551	PEFRA	3355	39985	#528# #525#	19171 \$6
_	: .a*	15135	35833	33335	¥511	1935	12212	95335	diffi	35413	35316	35553	11115	34131	15593	Mana
		11 F 1 1		#4501 50001 50001 5111	1836 12101	\$ 1763 13133	NAME OF THE PARTY				#R(): :::::::::::::::::::::::::::::::::::	*****			11111	
	<u>, </u>			11242	HH	1111		341) 33333 33348	11111	47344		1134 2222 21347	11111 121 17			Will.
	1	77311			Sanak Sanak		21112 21112		10 m 3 m 3 m 3 m 3 m 3 m 3 m 3 m 3 m 3 m	11111 11111 11111		ana: Symbol	110770		41345	SEER

		# H			III III	44444	4444	11417	{# ? #\$			<u> </u>	H 17	
	HW77541	\$!!	pa. 1	11/11	Мu	47777	11777	11777	77777		45-11		if 585	##inf
	<u>.</u> (a	n. ==	141.7	100	PRAM IAN	44144	1 1111	14111	11111	44444	1111	рра	litt	10011
		Ž.E	717-7	3355	1713	14414	HHI	14144	11717	11111	4444	47.144	11111	H.
	<u></u> 's	. i	au di					17.12	mik	12,147	55511	ştiğt	\$45£	1187
	Marit	S B	aait1	77179	ŅŅ.		: 1 * * * 1 * - * 1 *	1 111	1 1 1 1	11227	35443	;;;;,·	part.	***
		. 1	1111	44744 48944		11111	11411	(14)	3.411	-1414	1414!	19755	B라śś	KŽŠIS
	Milit	3 a	-4424	1117	344	11111	1111	11111	2000	25-17	448.	19:41	भू। च ंबेल	8 - 3 e 4
	7		aaaa i		ii)a		1			1 * 1 *		1 1	1,.1	1.11
5C	Para 1	33	. 59	444	fys.							111.	11/4	7.4.
3	keper 1 11		# 1	44/4		1323	133	r in		ţæ,	1. 1	Ma	134	Įų.
ABLE		13 E	֓֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֞֓֓֞֞֞֓֞֞֞֞	11111		1177		· ·		₹.±*	: 1	. '	1.5	1 - 3 -
7			1,125	1111	1124	44144		gu	11:5	Ð.,	(· · · ·	: #	HH.	146
	ส์หลัก	,3 <u>s</u>	11114 11114	(3644) (4674)	l jyru	1313)	911	1111	2010	44.	. † 1	* .	(**)]	(til)
	,	. 1		1,14	• 69 8	nay i	, 1944.	TITITITI	1	, '	1.7	- 1	į į į	(1)
	持事業事業 (31	36 5	7954	1.55						101	1 5 V	1	44
			34.3		21121 4 1447	11111	33347	1, 141	44114	 	1111	1111	!!41)	17
	(Prival)	1 6	14.15	5555	\$. * \$	NAME.	1 1/14	1447	4746	path.		₹# # ."	र्ग्ड्इ:	€ *. `.
	F.	an July	3		1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 2 4 6 2 2 3 4 3 4 5 4 4 7 9 8		1		\$ 150 300 100 100 100 100 100 100 100 100 10	Hill Hill		100	
		'*								200				

		45345	11111	333	\$ 3335	33333		3333	3333	9 } }}	###	15/35	1355	19935	15131	133
	 Şı	11115	9:533	55553	1111	Hiji	33515	33555	5115	\$5555	11111	2!!!}J	15131	11111	75774	Mar
	::	11211	1555.1		34411		11333	1111	11111	13333	11131	11511	15153	3511	11135	11111
	4	55555	****	24424	173"3 173"3	43377	33413][[]]	1,125 1,135 1,135	12777	77771	îiiii	11111	11]]] _]	Hili	11111
•	:!	1533	1111	18313	11511	11111	1144	损损	456		#### #####	(#/# <u>)</u>	1011	11.51		71112
	8 31	13315		3531	\$\$\$92 350	#### #####	1144		tilsi	11(1)		i (iii)	11445	粉粉		11371
•	;!	69133		Hi		11:15	iiii	11381	(11)	Bill	Hill		iivii	iiii	H	::1114
(OJ	5 - 3 1	2 4484	55515	#535	1117	33333 	His	3333	fint	38141	15335	1111	1334	1111)	1333	911.
JNI	; ;	1331	HH	1111	HH	HH	\$! {}!	NAT	1335	31131	11111	filli		446	55111	1315
C (CONTINUED)	.: .;1	19555	1995	Hill	11435	Ш	iiii.	11.13	mil	1:33	15555	()13)	!!!!!	5337	<u>}}]]</u> :1	1111.
		11111		11122	1811		44374	11554				11111			nill Hill	11911
3-2C	43	13)5	34733 86232	Hill	11755	16:11	171.4	11111	MA	1331	Mili	11121			iiii)	343 21828
TABLE	.,	1831						1134								11110
Z	.;1	13115	1441		71511	1111		****	##1.# *:2:#	17711	elect	egg.	Die	(1740 (414)		151.
		55165	11111	1111		# T # T # T # T # T # T # T # T # T # T								10030		12111
	. 44	1555	1474	345)	11116	1113	1311	\$2 \}	11151	73.23 1011	11(7)		** 1×1 ** 1×1	1.111	145	10111
	!	11115	11111	331	111:1	5111		iiii	1337	l));i				1911	Effi	1111
	41		11511	3331	Tell Hand	11111	#1111 	11.00	133	1315	11.7	141 14 2012 15	100	.B.9	1335	2.44
	ţ	1221					137 S				1111					
į	. (inite Man	MH.				11121							
]	13331	iilii	iiii	11:11		14117		hin	1111		11111	444			

SECTION 4

RESULTS: EMISSION BY HOT H20

Results on emission measurements of 11 samples of pure H₂O vapor at 900°K, 1200°K, and 1500°K are presented in this section.

Pressures were varied from approximately 48 to 760 mm Hg, with a sample cell length of 7.75 cm. Figures 4-1 to 4-5 show emissivity curves replotted from spectra obtained with resolution schedule C (Table 2-1). As in the case of the CO₂ emissivity curves a small amount of information has been lost in the replotting. In a few cases it appeared that the automatic replotter did not move in straight lines between the points on some of the steep slopes. The error tended to make the emission lines appear slightly narrower than they should. The uncertainty in the emission curves is somewhat greater on the low frequency side, below approximately 3200 cm⁻¹, than in other portions of the spectrum. The greater uncertainty in this region is due to two factors. The first is that the recorder deflection in this region is only about 30% of full scale on the original spectra. The other factor is the error in fitting the spectrum to the background because the two curves converge so gradually that it is difficult to determine where they should meet.

Results of the calculations of \overline{q} and N are given in Table 4-1 in the same form as the CO results in Tables 3-1 and 3-2. Information about the contents of the tables is given just previous to Table 3-1.

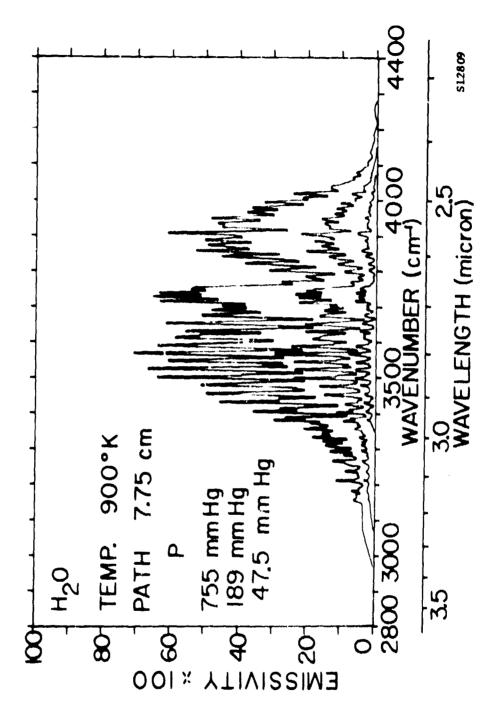


FIGURE 4-1. ENGSSIVITY CHRVZS FOR SAMPLES WI, W2 AND W5

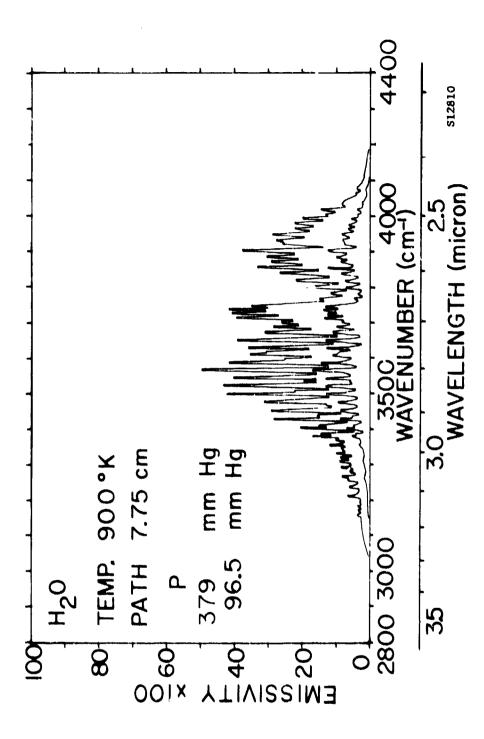


FIGURE 4-2. EMISSIVITY CURVES FOR SAMPLES W2 AND W4

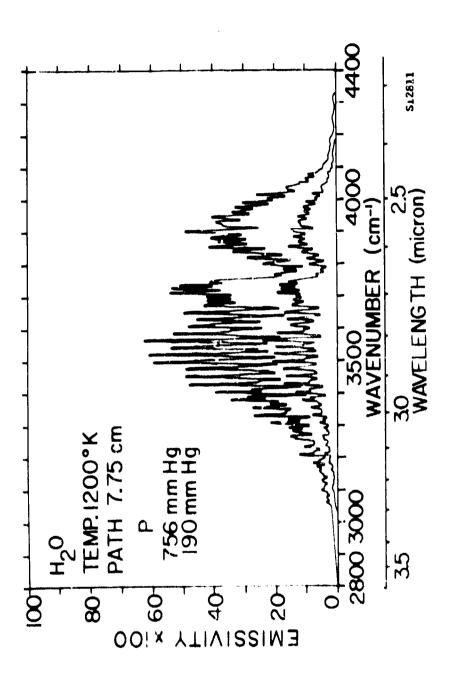
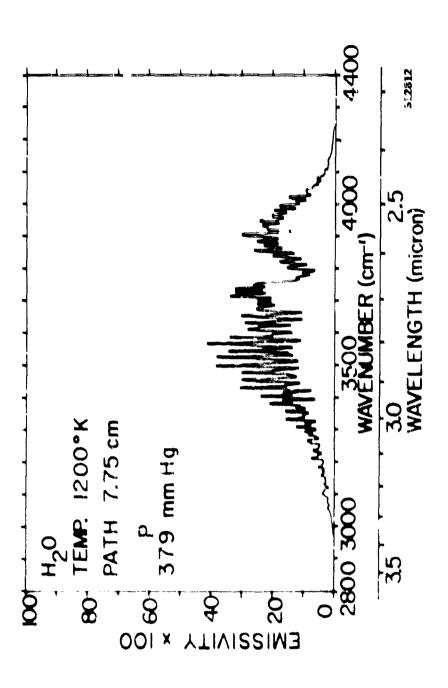
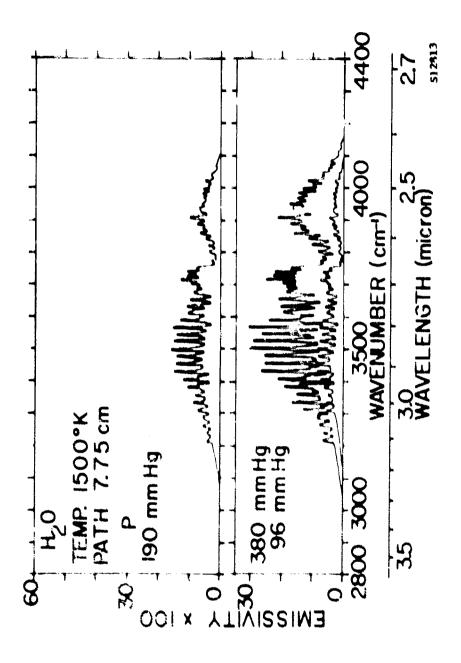


FIGURE 4-3. EMISSIVITY CURVES FOR SAMPLES 46 AND 48



FLOWE 4-4. ENGSSTYTT CHAYES FOR SAFEE AT



TICHE (-). EXISSIVITY CURTS FOR SAMPLES UP, WIO AND WILL

20 7

	1	:1	33233	1465	1111			\$5499 99999 \$643
	ส์เมื่อ	21	10010	्रसम्बद्धाः इ.स.च्या	15151	15111	11555	1311a aaaaa
	<u> </u>	1.0	14111	LIS	H	1111		<u> </u>
	delia	41		4 11 4	33553	X # # 3 E	31555	
	•	-	11111	¥ 4%	14118	11111	##### ################################	### 2222 ##############################
	dai.	÷.	23232		# W # \$ # 	11553	51131	ing Tagaa aaaaa
		. 1	_	46188		1111	1333	### H
		21	1383	****	15522	1111		43515 13.22
		-1	4	-1514	15352 15357 15357	11111	45314 11371	APARC HILL
	Acres	*						
		31		1111	\$5515 \$357			10 to 11111 HH 2 222
_	. 1	• •			1141 1111			•
4	della.	-31 	23121	ार समर	क्षति स्राप्त	15312 11121	15153 77878	11131 2222
ABLE	,	Ţ	!	1117	22451		111.3	
A8	ជ័យខែ	-34		4.4.1	1111	14575	1111	11111 1 1112
						33:3	3011;	
	'.	:	2222	110	1117			1111
 -	น์เบีย.	:!	22224 22222			****		iiii
 -	มีเนีย.			110	1117			Hill
 	delle.	45		1. **		**************************************		iiii
		-1		1. **		****	1112 1212 1212 1212 1212 1212 1212 121	MH was
		:1	.2223 .2233 	1: ** [21]				HIII and
	.iu	-15	.2223 .2233 	1: ** [21]		TOTAL STREET	1112 1112 1112 1112 1112 1112 1112 111	
	34.	11	.2223 .2233 	1: ** [21]				MII and MII an
	.iu	-15	22217 22217 272217	411	1011 1011 1011 1011 1011		1943 1943 1943 1943 1943 1944	
	34.	11 11 11 11 11 11 11 11 11 11 11 11 11	22217		10 10 10 10 10 10 10 10 10 10 10 10 10 1		1943 1943 1943 1943 1943 1943	
	ad. ade.		22217 22217 272217	411	1011 1011 1011 1011 1011		1943 1943 1943 1943 1943 1944	Will areas Will a
	34.		22217		10 10 10 10 10 10 10 10 10 10 10 10 10 1		1943 1943 1943 1943 1943 1943	

	ָּ֖֖֖֖֚֚֚֚֚֚֚֚֚֚֚֚֚֞֓֝֝֝֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓֓	11111	44444	11111	11111	ififf	44434	+++++	+++++	11111	44444	14563	92845	45615	FR99	22453	14164
	; _31	3444	+++++	****	1111	4444	44444	iiiii	iiiii	11111	11111	31355	24308	*****	E127F	*****	C#3##
	- <u></u> -	+++++	11111	+++++	+++++	4444	+++++	+++++	44744	++++	11111	44444	+++++		Figer	12455	19832
	Jė	+++++	11111	****	*****	11111	11111	****	11111	+++++	****	 	iiiii	184	11111	11335	11111
	; ; ;	+++++	44444	99444	44444	4444	99 9 44	*****	्वन्त्	44444	11111	titt	44444		14355	della	27812
	41	****	+++++	4444	*****	++++	****	11111	14444	44444	****	iiiii	iiiii	258	3013R	EARAS	****
•	.!	11111	19853	38934	ERGEE	1111	32443	13553	54611	87888	14225	1442	15255	33665	11111	12925	53454
	•							*****	****				****				
		55535	11111	11111	11111		13333	*****	11127	*****	2332:	30114	55935 *****	75722 22423	37923	33333 33333	35333 11123
_		++++	44444	+++++	****	*****	****	11111	11111	HILL	:1352	1111			17555	55553	11111
_	6 	*****	32322	44444	34444	33322	22222	34843	****	1 4554	68818	11151	25251	15114	14445	1992	13335
₹										22222	-11	15494	21417	1111	11111	11511	1:11
ONTINUE	, "	*****	*****	*****	*****	77777	77777	77:77	****								
20	- 41	****	44444	44444	++++	titit	****	+++++					1111	11111	11111	13555	35444
<u>Ö</u>		<i>कुरुकुत्</i> स	+++++	वर्षस्य	44444	44444	4444	<∴.!	51644	11111	14411	20111	11/4	His		15511	!!!!!
,	; 41	4444	44444	****	4444	+++++	+++++	:	43355	111	****	30815		444.4	44952	35535	titt
4	.!	Ī.,.,		44444			13:13	11 111	44444	44442	!!	71111	11115	1163	13777	14543	11111
BLE	i Ji		+++++		44444	44444	,,,,	4444	*****	****	:	11714	15554	****	!!!!!	1371	:41
TAB		 										₹1	41411	4,915		14*11	11161
		3 8 4 6 4	+ } + + +	44444	न्त्री	इन्द्री इ	44444	43444	<u> इन्हर्न</u>	+444-	44444	*****		• • •			•
	ان	****	4444	44444	++++	11111	7999	+++++	++++	++++	+++++	,,, ;;	37.4.4.4	!!::!	!!!!!	1161	*****
•	- [++++	44444	कृत्वक	45444	++++	11111	ju [ya	****	4444	*****	*****	*****	*****	4443	11111	!!!!!!
	; 41	++++	****	****	ifiti	****	riii	****	++++1	+++++	*****	ittii	++++	iiiti	;;;, •	1.111	****
_	.!	++++	4444	4444	1::::	. 9717	++++	الم الم	***	44244	44274	1111	444,4	++++		2,442	444-
	•	Ì	22.24	42312	3223	23222	12427		22:22	دددد	44	2.2.1					- -
	از	1 1 1 1 1	77777	777.7	: * * * *	1111	- 1-1								*****		*****
		13511	45.33	1111	11)	1!!!!	15:11	11:44	1411		ille	illit	1933		16!!	11:11	
				11111		11/4	1	lika	ini		lijli	illi		1		1111	11771
		5::15	15161	m	iilii	1111	11111	tuli	illi	\$ \$ \$\$\$\$	20116	11111	His	Hite:	1111		1111
	1 ,	1		illi	Hill	11:11	1111				11111	Hli	11111	19:11	1551	1111	1111

#1 | 1997 | 1997 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 1999 | 20101 20112 12010 12010 10010 10010 10010 12010 12010 12010 12010 10010 10010 10010 10010 10010 ...| 1992 - 1993 - 1993 - 1993 - 1993 - 1993 - 1993 - 1993 - 1993 - 1993 - 1993 - 1993 - 1993 - 1993 - 1993 - 1 TINUED The file that trait toth tothe colle colle tothe total trait total trait that the 44 22752 20732 25723 75737 25732 25752 25752 25752 25752 37752 37752 37752 37752 37752 37752 37752 37752 37752 ing dien inse een een een een inse een een een een Marrie agree arrie arrie arrie arrie 1844 - 12359 93395 93395 93393 93393 95331 95351 95353 93353 93353 93335 karan santa anna asasi sirin santa santa santa santa sirin sirin sirin sirin sirin santa santa anna sirin Karan santa anna anna anna santa baha baha baha santa santa santa santa baha santa baha santa

	::	1111	H		1111			1135		!!!!!							
•	31	11111	*****	11111	22131	*****	1111	1111	15111	51534	11111		25.55	11111	13331		41511
_	.1																
;	41	58553	13145	35535	19735	****	33355	55555	51515	13455	53334	15553	21111	11111	11113	11111	33533
	- 1										34455						
ī	*1	!									33111						
-					_						15111						
1	,																
	11	12111	11111	19533	;;;;;	42223	11111	11111	11411	11:11	11111		أأأأ	11111	11111	12111	
	:	3355	1111	933	35355	555	1411	55555		1111	11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	33.33	11111	13555	5555	1555	5555
(C3)		25553	11113	15111	****	11111	11157	-	19191	42222		12112	\$4.5×4	11111	11:11		
¥.	<u>.</u>	1111		33434	11111	11111	11111	1111	1451	2534	[4]][11111	11111	13173	11655	15111	
CONTIN	£ .	I														18741	31781
ő.											11111				,	12121	1111
9	, ;; i	11777	11111	1111	11111	11111	11111	13555	\$5.55 5.55 5.55 5.55 5.55 5.55 5.55 5.5	11111	HH	1000	Hill	11111	11111	11111	1111
₹.	41	133	44372	12.22	1141		31333	1111	22:11	44111	-1413	12027	\$2442 1444	17111	1117.	311: 12:62	
4			IIII		141	1111	140	1111		1111	1911	Hill	Hill	1111	11711	1111	17461
TABLE	:	15335	54355	33553	1233	33335	35545	59959	15:33	55533	1311	33455	11111	34115	11151	11111	11411
AB.		2111	17811	11111	4411	2000	55455	11113	11111	1117:	11111	('1)[11:11	1111	£7114	15111	11111
 		1															
		1277	1333	17:33	3233	2111	1111	1233	1117	1111	1111	177	1377	3333	****	1000	100
						1111	1111	. 3133	1515	11111	11111	11111	17371	15151	11111:	11111	33337
	i :	11111	59535		1231	11:11	4131	51355	3553	1133	1111	2 4 2 3 2	4443	13311	1:121	!!!!	12399
		11111	1111	1111	1111	1111	(11)	11951	Hiji	1111	1883		11111	15111	15611	15114	11111
		1															
		1111		1111	1211	Hill				115		Lilli			1,343	355!!	
	,		illi	1111	1 : !!!	Hill	! !!!!		Hilli			1111	[35]	11111	His	11111	
	1			1215			6 9533	1331		1231	::::::	Hill	1111	11111	11111	HIII	
	-	11111	ı Iiii	1 1111	, **) ş	. ::::	1 (32)										

	•	:		35353	1111	1,51,12	77745	33533	•				2222	12222	2222	22222	22221	-1111
-	•	1			33333													
	بر	4						32234		44444		*****	40000			44444		
		:					22222	*****	*****	44444	22222	*****		22424	****	*****	48.48	*****
	A				15515		****	22222	22222	22222		****	****	22222		****	22222	46666
					1915	11111	!	11233	22222	*****	22222		*****	*****	44544	22222	22222	22222
	; ;		55333	19355	31115	55555	1		****	22222	22222		*****				22222	22222
			1111	13531	13413	11611	3331	13555	13515	53355	1555		5533			!!!! .		
	:	15	19551	*****	33335	35355	11111	11111	12535	11111	3555	11551	45555	74574	11115	5111.		22222
•				3555	7.7	14153	24528	19111			****	14431	314	****	11111			
<u>~</u>	•	١				11111								*****	*****	22222	22222	22454
Ш	14	: 4		Parts	13515	47248	55312	****	1515	45533	1175	13368	::::::	***	11111	11133	22222	22122
(CONTINUED)				31311		33535	11111	31353	19111	11111	1			22434	11111	22222		22222
Z	-		54555	11555	35485	15153	11111	1541	15131	11511					20222	22322	22222	22222
9			****	1000	43135	44634	2321		11111		245			11,,,	32323	22222	14444	22222
7			11417	22612	HHI	31113	1555	11511	13335	13455	11111	51533	3333	55,,,,	22222		22222	22222
4		_	111		1865			11111		1:151	11111	11	2222	22224	24322	32224	22222	22222
BLE	:	,,	11535	11111	33355	55935	4444	94725	\$ 15 5 5	33355	33533	49	22222		22222	44444	42444	
IA		_1	11111			11111				1111				44444	22224	22222	2222	2222
	٤	1		Hii						78755			2222	33244	يديد	2222	22222	22222
	;		22333	11555				14321	11111	11444	22223	33344	22222	-1811	11111	42412	11111	21411
		18	11333	32131	33734	15111	53322	42222	42024	22222	2222	22224	34444	11111	22222	44444	22222	****
		:	<u>iiii</u>	11111	11:11	11	44444	44444	14114	22223	22222	22332	فتتتا	-1444	22443	24222	adada	20222
	•	71	11111	51111	1991	11		32442	12112	23222	20222	44444	22322	22332	2222	22222	22222	*****
			Hiii	11111	iilil	11111	1:1:1	3151	Hiii	11.11	iiii	15633	1015	13111	\$2515	nia	Hiil	
		1		1111									22411					
	,		11111	*****		11111		11111	11111	11111	TITII	11111	11111	XCRER Tiril		*****	#####	##### #####
)						****				*****		55335		# 6 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			inite iiiiii

SECTION 5

TRANSMISSION OF RADIATION FROM HOT CO, THROUGH COLD CO,

Introduction and Theoretical

In dealing with the detection of hot gas sources such as rocket plumes and jet exhausts, the problem of transmission of the infrared radiation through the atmosphere is as important as the problem of emission by the hot gas. This is particularly true since HoO and CO, the main radiating constituents in flames also occur in the atmosphere. Since the emissivity of a gas is large at the same frequencies as the absorptance, the gases tend to radiate at frequencies where there are atmospheric absorption bands. Much work on the transmission of atmospheric gases has been done so that it is now possible to estimate the transmittance of atmospheric paths covering wide ranges of path length, pressure and atmospheric composition. From these estimates it is possible to determine the fraction of the radiant power from a source that is transmitted if the spectral radiance of the source is constant over the spectral interval being considered. However, if the spectral radiance of the source varies rapidly with wavenumber, as is frequently true for a hot gas, the amount of transmitted power cannot be determined directly from the transmission data that are available. The reason for this can be explained by the use of the simplified model illustrated in Figure 5-1.

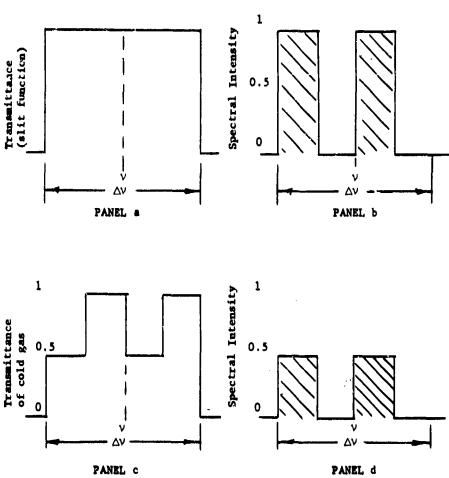


Fig. 5-1
A Simple Model Showing the Effect of Coincident Lines

The upper portion represents the slit transmission function of the monochromator, which is zero outside of the spectral interval $\Delta\nu$ wide and centered about ν . Of course, this is not a realistic slit function, but it is simple and will serve the present purpose. Panel b represents the true spectral intensity of a hot gas source having two emission lines in the interval $\Delta\nu$; each is assumed to be 0.25 $\Delta\nu$ wide and to have unit intensity in arbitrary units. In observing this source with a monochromator having the slit function indicated the emission lines would not be resolved, and with the monochromator set at ν , the signal on the

detector would be proportional to the average intensity over $\triangle v$. Now assume that the radiation from the hot gas passes through a sample of cold gas having a true transmittance curve like that shown in panel c of Figure 5-1. In this example the absorption lines of the cold gas are coincident with the emission lines of the hot gas. Panel J of the figure represents the spectral intensity of the transmitted radiation obtained from the product of the curves in panels b and c. The maximum spectral intensity of each line will be reduced to one-half unit, and the signal will be reduced to half its size by the cold gas. The observed transmittance of the cold gas, defined as TR(v), when used with this gaseous source of radiation is 0.5. It can be seen that if the spectral intensity of the radiation incident on the gas were constant over $\triangle v$, the observed transmittance $T_C(v)$ at v would be 0.75, the average of the true transmittance.

Thus, it is apparent that the fraction of the radiation transmitted by a cold gas sample having unresolved "structure" is dependent on the structure of the emitting gas. In the example given here, in which the emission lines and absorption lines are coincident, $T\pi(v) \leq T_C(v)$. It is apparent that if the absorption lines were displaced so that they occurred in between the emission lines, $T\pi(v)$ would be greater than $T_C(v)$.

When observing hot CO,, for example, through an atmospheric path containing cold CO,, it is expected that many of the absorption lines will coincide with the emission lines, with the result that $T\pi(v) < T_{c}(v)$. The problem is complicated by the fact that there are many lines which contribute significantly to the emission by hot CO, but are negligible in cold CO, $^{(v)}$. The relative intensities of many of the lines also change considerably as the CO, is heated. Thus, one expects that there would be some, but not complete, correlation between the lines of the emitting and absorbing gases.

The ideal method to investigate $T_n^*(v)$ and its deviation from $T_n(v)$ would involve a system in which a variety of cold samples could be contained in an absorption cell; and for sources of radiation one would have both a hot gas sample and a continuous source, such as a Nernst glower. It would be desirable to be able to vary the optical thickness, pressure, and temperature of the hot gas and to have it at uniform pressure and temperature. An explained in Section 1, it is not feasible to use a gas sample in the furnace as a source of radiation because of radiation from the windows; and an open flame has the disadvantage that the temperature is not uniform and there are limitations on the pressures and optical thicknesses which can be obtained.

Although it is not feasible to use, a sample in the furnace as a radiation source, it is possible to make transmission measurements under some conditions which enable one to calculate the value of $T_{\rm R}^{\rm c}(\nu)$ for a cold sample that would be observed if the sample in the furnace were the source. The measurements are made in a manner similar to those described in Section 3 and 4, except that the optics tank is used as an absorption cell in "series" with the furnace. Absorption spectra are made in sets of three: the first with a sample in the furnace and the absorption cell evacuated; the second with the same sample in the furnace and another sample in the absorption cell. The third spectrum is then obtained with the furnace evacuated and the sample left in the absorption cell. From the three spectra, values of $T_{\rm u}(\nu)$, (hot gas); $T_{\rm HC}(\nu)$, (hot and cold gas); and $T_{\rm c}(\nu)$, (cold gas), respectively, are calculated at several frequencies throughout the band. It is shown below that the value of $T_{\rm c}(\nu)$ at these same frequencies can be calculated from

$$T_{C}^{*}(v) = \frac{T_{C}(v) - T_{HC}(v)}{1 - T_{H}(v)}.$$
 (5-1)

Derivation of T*(v)

With the monochromator set at frequency (ν), D (ν) is the recorder deflection observed with no sample in the furnace or in the cold absorption cell, using a glower source.

$$D_{o}(v) = \int_{\Delta} N(v) C(v) f(v) dv, \qquad (5-2)$$

where N(v) is the spectral radiance of the glower and C(v) is a variable quantity which depends on the aperture and transmittance of the optical system, not including the slits, and on the sensitivity of the detector and amplifying system. f(v) is the slit function of the monochromator; i.e., the transmittance of the monochromator over the interval Δv passed by the slits. If a sample of gas is put in the cold cell, with all other parts of the optical system kept the same, the recorder deflection will be given by

$$D_{C}(v) = \int_{\Delta v} N(v) C(v) f(v) \exp \left[-k_{C}(v) u_{C}\right] dv.$$
 (5-3)

k (v) is the true absorption coefficient of the cold sample as would be observed with an instrument having infinite resolving power, and u is the optical thickness of the cold sample. With a Hernst glower and an optical system of the type usual in the present investigation, it is usually safe to assume that N(v) and C(v) are constant over Δv (from 5 to 25 cm⁻¹) and can be removed from under the integral sign.

The observed transmittance $T_C(v)$ is given by

$$T_{C}(v) = \frac{D_{C}(v)}{D_{C}(v)} = \frac{\int_{\Delta V} f(v) \exp\left[-k_{C}(v) u_{C}\right] dv}{\int_{\Delta V} f(v) dv}.$$
 (5-4)

Similarly, the observed transmittanc' $T_{\mbox{\scriptsize H}}(\nu)$ of the hot sample alone is given by

$$T_{H}(v) = \frac{\int_{\Delta v} f(v) \exp \left[-k_{H}(v) u_{H}\right] dv}{\int_{\Delta v} f(v) dv}, \qquad (5-5)$$

where $k_{\rm H}(\nu)$ is the true absorption coefficient of the hot gas and $u_{\rm H}$ is its optical thickness.

The observed transmittance of both the hot and cold samples in "series" is

$$T_{HC}(v) = \frac{\int_{\Delta v} f(v) \exp \left[-k_{C}(v) u_{C}\right] \exp \left[-k_{H}(v) u_{H}\right] dv}{\int_{\Delta v} f(v) dv}.$$
 (5-6)

Since we are interested in relating the quantities given by equations 5-4, 5-5, and 5-6 to Tr(v), the transmittance of the cold sample that would be observed if the hot gas were used as the source of radiation, we assume another optical and detecting system which is different from the present one except that it must have the same slit function f(v). We define Dy as the signal or recorder deflection observed at frequency v if a blackbody at the temperature of the hot gas were viewed through the assumed system with no absorbing gas in the beam. If we replace the sensitivity constant C(v) in equation 5-3 by C*(v) then Dy is given by

$$D_{\underline{u}}^{\underline{B}}(v) = N^{\underline{B}}(v) C^{\underline{u}}(v) \int_{\Delta v} f(v) dv, \qquad (5-7)$$

where $N^{\mathbf{B}}(\mathbf{v})$ is the spectral radiance of the blackbody.

If the hot gas sample instead of the blackbody were viewed with the same system, the signal would be

$$u_{H}^{*}(v) = C^{*}(v)H^{B}(v)\int_{\Delta v} f(v) \left\{1-\exp[-k_{H}(v)u_{H}]\right\} dv, \qquad (5-8)$$

where the term in braces is the true emissivity of the hot gas. Now if the radiation from the hot gas passes through the cold gas sample, the observed signal will be

$$D_{HC}^{+}(v) = C^{+}(v)N^{B}(v)\int_{\Delta v} f(v) \left\{1-\exp[-k_{H}(v)u_{H}]\right\} \left\{\exp(-k_{C}(v)u_{C})\right\} dv.$$
(5-9)

By the definition of $T_{c}^{*}(v)$, it is given by D_{HC}^{*}/D_{H}^{*} . Therefore $T_{c}^{*}(v)$ =

$$\frac{\int_{\Delta v} f(v) \exp[-k_{C}(v) u_{C}] - \int_{\Delta v} f(v) \exp[-k_{H}(v) u_{H}] \exp[-k_{C}(v) u_{C}] dv}{\int_{\Delta v} f(v) dv - \int_{\Delta v} f(v) \exp[-k_{H}(v) u_{H}] dv}.$$
(5-10)

It is noted that if each term in equation (5-10) is divided by $\int_{\Delta V} f(v) dv$,

$$T_{\overline{C}}(v) = \frac{T_{C}(v) - T_{HC}(v)}{1 - T_{H}(v)} = \frac{T_{C}(v) - T_{HC}(v)}{\epsilon_{H}(v)}$$
(5-1')

Thus, it is possible by the use of equation (5-11) to determine $T_{\nu}^{+}(v)$ from the three measurements of transmittance made at the same value of v. It should be noted that the measurements must be made with the same slit function; the calculated value of $T_{\nu}^{+}(v)$ then applies to the same slit function.

Since the effect of correlation between the lines appears as a difference between $Tr(\nu)$ and $T_C(\nu)$, the measurements are made under conditions in which this difference can be determined with reasonable accuracy. In this regard the technique described is not useful for values of $T_C(\nu)$ or $T_C(\nu)$ near zero or near unity. If $T_C(\nu)$ is near zero or unity, of if $T_C(\nu)$ is near zero, the difference between $T_C(\nu)$ and $T_C(\nu)$ is so small that it cannot be determined with much accuracy. If $T_C(\nu)$ is so small error in its measurement will give rise to a large error in the calculated value of $T_C(\nu)$, since the denominator in equation (5-1') becomes small. For this reason, measurements of $T_C(\nu)$ have been limited to spectral regions over which $T_C(\nu)$ and $T_C(\nu)$ lie between 0.1 and 0.9. In order to investigate different spectral regions, the pressures and optical thicknesses of the samples are changed so that $T_C(\nu)$ and $T_C(\nu)$ lie within the prescribed limits in the desired interval.

In the discussion of the simple model illustrated in Figure 5-1, it was noted that $T_R^*(\nu) < T_-(\nu)$ if the emission lines are coincident with the absorption lines, and $T_C^*(\nu) > T_-(\nu)$ if the emission lines occur between the absorption lines. If the positions and strengths of the emission lines occur at random with respect to the absorption lines, then $T_C^*(\nu) = T_-(\nu)$. When $T_C^*(\nu) = T_-(\nu)$, there is said to be no correlation between the emission lines and the absorption lines. It can be seen from equations 5-1' that $T_{\rm HC}(\nu) = T_{\rm H}(\nu) \times T_{\rm C}(\nu)$ under this condition.

Several measurements have been made in the spectral region near 3700 cm with hot H₂O in the furnace and cold CO₂ in the absorption tank; and it has been found that $T_{\overline{x}}(v) = T_{-}(v)$. This result is not surprising since it can be seen from high-resolution spectra that there is little, if any, correlation between the positions of E₂O lines and CO₂ lines. It has also been shown previously that the product of the transmittances of a water vapor sample and a CO₂ sample obtained separately is equal to the product of the two samples in series, when both samples are at room temperature.

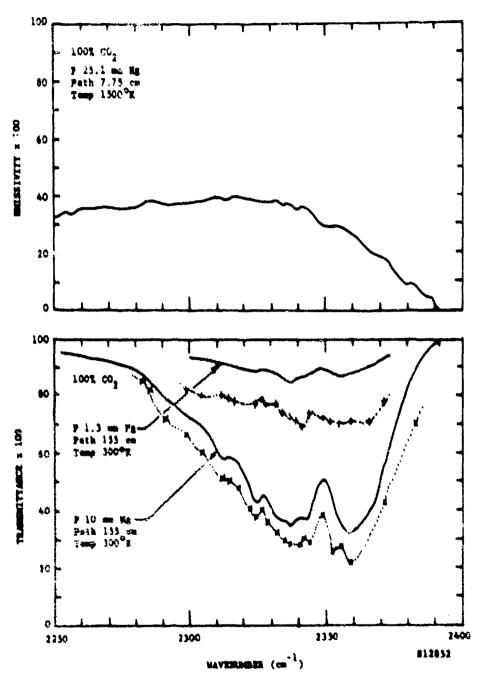
It can be seen from equation (5-6) that $T_{\rm e}(v) = T_{\rm e}(v) = T_{\rm e}(v)$ if either $k_{\rm e}(v)$ or $k_{\rm e}(v)$ is constant over Δv so that the emponential factor including it can be removed from under the integral sign. Thus, a difference between $T_{\rm e}^{\rm e}(v)$ and $T_{\rm e}(v)$ occurs only when there is unresolved "structure" in both the emission spectrum and the absorption spectrum. It follows that $k_{\rm e}(v)$ and $k_{\rm e}(v)$ will be constant over one spectral slit width as Δv is made very small so that it is much less than the half-width of all the lines. For the pressures, temperatures and slit widths encountered in the present study, Δv is 2 pr 3 orders of magnitude larger than the half-width of the spectral lines".

Results

In the upper portion of Figure 5-2 is shown a curve relating emissivity to wavenumber for the CO, sample indicated; and the solid curves in the lower portion are transmittance curves for two cold samples. The x's on the dotted curve in the lower panel represent values of $T_{\pi}^{*}(v)$ which were calculated for the 10 mm Hg sample if the hot sample represented in the upper panel were the source. Values of $T_{\pi}^{*}(v)$ were determined by inserting into equation (5-1') the measured values of $T_{\pi}^{*}(v)$ and $T_{H}^{*}(v)$ for the samples involved. Similarly, the +'s represent values of $T_{\pi}^{*}(v)$ for the 1.3 mm Hg sample with the same hot sample as the source. It is seen that $T_{\pi}^{*}(v)$ is considerably less than $T_{\pi}^{*}(v)$ over most of the spectral interval where it can be calculated. If one compared values of $A_{\pi}^{*}(v) = 1 - T_{\pi}^{*}(v)$ and $A_{\pi}^{*}(v)$ in tead of $T_{\pi}^{*}(v)$ and $T_{\pi}^{*}(v)$, it is seen that $A_{\pi}^{*}(v)$ is more than twice as great as $A_{\pi}^{*}(v)$ and $T_{\pi}^{*}(v)$, it is seen that $A_{\pi}^{*}(v)$ is more than twice as great as $A_{\pi}^{*}(v)$ are considerable portion of the spectrum of the '.3 mm Hg sample. The curves in Figures 5-2, 5-3, and 5-4 are based on spectra obtained with slit widths given by Resolution Schedule B in Table 2-1.

It is noted that the samples represented in Figure 5-2 are at relatively low pressures; thus one would expect the spectral lines to be narrow, giving rise to a large variation in the absorption coefficient k(v) over a spectral interval corresponding to one slit width. Since the "structure" in the band gives rise to the difference between T and Tt, one would expect this difference to be greatest for lowest pressures.

Figure 5-3 includes a similar set of curves with the hot semple composed of a dilute mixture of CO₂ in N₂, thus producing a sample of low optical thickness but high pressure. It is well known^{1,2} from previous transmission studies that the structure of a band is decreased by increasing the pressure and decreasing the optical thickness. On this basis one would expect that the difference between T_C and Tg would be less for a given cold sample when the hot sample is at high pressure and low optical thickness than when the hot sample is at low pressure. Comparison of Figure 3-3 with Figure 3-2 same to bear out this expectation in the case of the 1.3 mm Mg sample. However, the difference between T_C and Tg for the larger cold samples (9 mm Mg and 10 mm Mg) is not greatly different in the two figures. Since complete "smoothing" of the structure of either the hot or cold sample would eliminate any effect of correlation, it can be concluded from Figure 3-3 'hat a significant amount of structure still exists in the hot sample ht a pressure of 1130 mm Mg.



Pig. 3-2. Comperison of T (v) with T2(v) for case of emitting end absorbing gas at low pressures. *'s and x's represent calculated values of T2(v) for the cold samples with the not sample as a source.

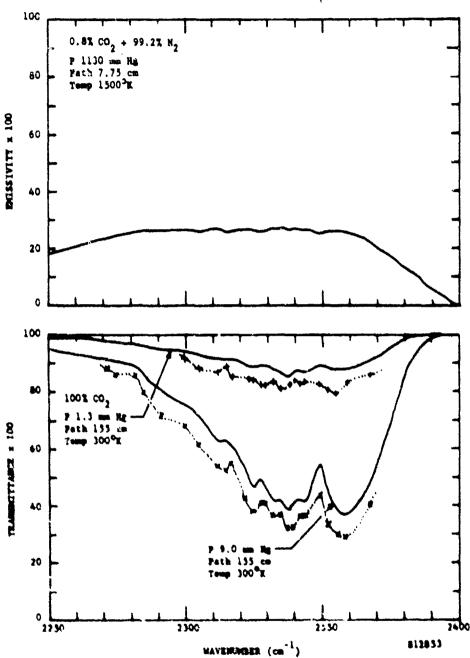


Fig. 3-3. Comparison of T (v) with TY(v) for case of emitting gas at high professes and absorbing gas at low pressure.

Figure 5-4 shows two pairs of curves obtained with larger samples to investigate the low wavenumber side of the region. The large cold samples were obtained by using the multiple-pass mirror system in the optics tank as shown in the left-hand portion of Figure 2-1. The x's adjacent to curve A (lower panel) represent calculated values of T*(v) for the same cold sample when the hot source is the one whose emissivity is shown by curve A in the upper panel. Although the calculated values appear to lie close to the steep portion of the curve, most of them lie below the curve by an amount corresponding to a difference in transmittance of approximately 0.04. This difference is believed to be significant, and one can conclude that there is some correlation between the emission lines and the absorption lines in this region.

It is noted that curve B in the lower panel contains a region of low transmittance between 2000 and 2150 cm⁻¹, but emissivity curve B in the upper panel contains no corresponding maximum. Since the gross structure of these two spectra are greatly different in this region, it is of interest to check for correlation between the emission and absorption lines. The x's adjacent to B in the lower panel represent values of T*(v) calculated by using the hot source corresponding to B in the top panel. With the exception of 2 or 3 points, the x's seem to fall very close to the curve, indicating that there is very little, if any, correlation between the positions and intensities of the lines in the two samples. This result is not surprising since the gross appearances of the spectra of the samples are greatly different, indicating that the relative contributions of the different vibration-rotation lines are different.

Figure 5-5 shows two sets of curves for the region near 3700 cm which are based on spectra obtained with slit widths given by Resolution Schedule D in Table 2-1. As in the previous figures, the +'s and x's represent calculated values of $T_{\rm C}^{\star}(\nu)$ for the cold samples with the sample represented in the upper panel as the source. It is seen that the calculated values of $T_{\rm C}^{\star}(\nu)$ fall slightly below the curves of $T_{\rm C}^{\star}(\nu)$, as was found to be true for the 2350 cm⁻¹ region.

Future Plans

The multiple-pass absorption cell having a base length of 29 meters will be used to contain samples of rather large optical thickness and very low pressure in order to investigate the "line correlation effect" under conditions where it should be greatest. The shorter cells have been used in the past because of an unusual delay in the delivery of the big mirrors for the longer cell. A flame of CO₂ produced by burning

\$

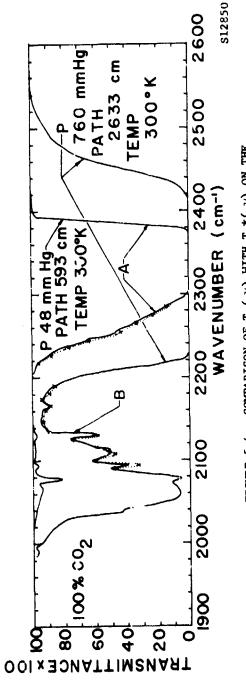
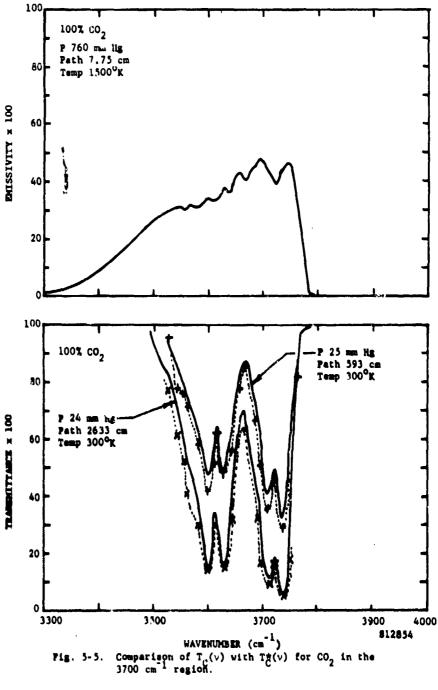


FIGURE 5-4. COMPARISON OF $T_c(\ \nu)$ WITH T *($\nu)$ ON THE LOW FREQUENCY SIDE OF 2350 cm⁻¹ CO₂

a

O

3



CO in O will be used as an optically thin source; i.e., $T_H \supseteq 1$. The for cold samples can be measured directly by comparing the signal from the flame after passing through the sample, to the signal with the absorption cell evacuated. The radiation from the flame will be chopped between the flame and absorption cell.

Similar measurements will be made with H₂O samples in till long absorption cell and in the furnace. H₂O flames will be produced by burning \bar{n}_2 in O_2 .

SECTION 6

REFERENCES

- Carmine C. Ferriso, "High Temperature Infrared Emission and Absorption Studies," Sci. Rept. Jan. 1961 to Aug. 1961, AFCRL, Contract AF 19(604)-5554. Several other related reports have been published by other workers at General Dynamics, including Harshbarger and Malkmus.
- 2. R. H. Tourin, J. Opt. Soc. Am., <u>51</u>, 175 (1961).
- 3. D. K. Edwards, J. Opt. Soc. Am., 50, 617 (1960).
- 4. U. P. Oppenheim and Y. Ben-Aryeh, Reports to be published. A preliminary account of the work was given at the Ninth International Symposium on Combustion, Cornell University (1962).
- 5. M. Steinberg and W. O. Davies, J. Chem. Phys., 34, 1373 (1961).
- 6. J. U. White, J. Opt. Soc. Am., 32, 285 (1942).
- 7. See for example, D. E. Burch, D. A. Gryvnak, and D. Williams, Appl. Opt. 1, 759, (1962).
- 8. D. E. Burch, E. B. Singleton, and D. Williams, Appl. Opt., 1, 359, (1962).
- 9. See for example, G. N. Plass, J. Opt. Soc. Am., 49, 821 (1959).
- 10. D. E. Burch, J. N. Howard, and D. Williams, J. Opt. Soc. Am., 46, 452 (1956).
- 11. L. D. Kaplan and D. F. Eggers, J. Chem. Phys., 25, 876 (1956).
- 12. See for example, W. Benedict, R. Herman, G. Moore, and S. Silverman, Canad. J. Phys., 34, 830, 850 (1956).
- 13. The regulators are manufactured by Fisher Governor Company and sold for approximately \$7.00 each.

APPENDIX A

FURNACE AND SAMPLE CELL

The furnace was designed and built as shown in Figure A-1 by the members of the Materials Department of the Aeronutronic Research Laboratories under the supervision of Dr. W. M. Fassell, Jr. and Mr. Robert Hale. It was designed to heat gas samples contained in a small cell located in the center portion of the furnace to temperatures as high as 2000° K.

Heat is provided by three resistance elements composed of Mo wire wound on McDanel AP35 alumina (Al $_{20}$) tubing which has an I.D. of approximately 3.8 cm and wall thickness of 0.3 cm. The alumina tubing is more than 99% pure and is impervious. A ceramic substance which is put on in the form of a paste made from pure Al $_{20}$ powder and water is used to hold the coils of the heater elements ap rt. Most of the heat is supplied by the main heater which is approximately 35 cm long. The other two heaters, called end-heaters, are each about 6 cm long and can be controlled independently to provide a reasonably uniform temperature. Two different sample cells have been used to date; the shorter one, which is 7.65 cm long at room temperature, can be heated to 2000°K with a maximum temperature variation of $^{+}$ 5°K along the length of the cell. It is not possible to maintain this good a temperature uniformity with the longer cell (30.6 cm) above approximately 1500°K.

The portion of the furnace surrounding the sample cell is filled with argon, which is infrared inactive, in order that there be no absorption or emission in the sections where there are large temperature gradients. The pressure in the "argon section" is maintained approximately equal to that in the sample cell in order to minimize leakage between the two sections and to avoid rupturing of the very thin sapphire windows on the sample cell. During operation the argon is flushed continuously, entering one end and leaving the other.

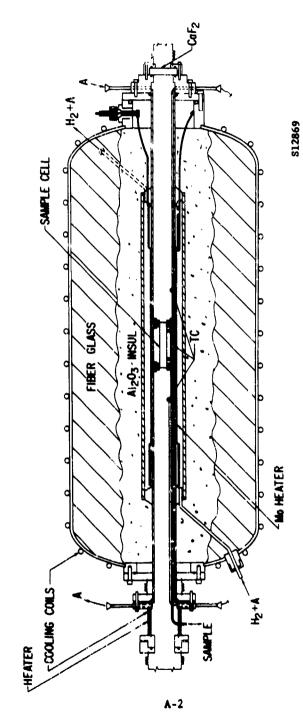


FIGURE A-1. DIACRAM OF FURNACE AND SAMPLE CELL

The furnace can be joined to the source tank and optics tank by flexible bellows as shown in Figure 2-1. CaF, windows are used on the ends of the furnace where the temperature does not exceed 600 to 700°K. "O"-rings of silicone rubber are used as seals between the different sections of the furnace and as gaskets for the windows.

The heating coils are protected on the outside by a larger ${\rm Al}_2{\rm O}_3$ tubing. Around this tubing are placed ${\rm Al}_2{\rm O}_3$ pellets for insulation in the region where temperatures are too high for fiberglass, which is used in the outer part of the furnace. The cylinder containing the ${\rm Al}_2{\rm O}_3$ tubing and insulation is made of steel approximately 0.6 cm thick and is approximately 80 cm long. As indicated in the left-hand portion of Figure A-1, the center piece of alumina tubing is connected to the steel index by use of two flanges joined by flaxible lellows in order to provide room for expansion.

The section which is outside of the core of the furnace and contains the insulation is sealed from the atmosphere and from the center section of the furnace. In operation this portion is flushed with a mixture of 10% H, and 90% argon at a rate of approximately I liter per minute. This gas mixture, which is directed past the windings as indicated in Figure A-1, is used to provide a reducing atmosphere around the Mo windings to prevent oxidation. The pressure of the Ha + argon mixture can be controlled, during flow, from approximately 50 to 1500 mm Hg. At temperatures higher than about 1500 K the pressure is maintained approximately equal to that in the argon section to minimize strain on the alumina tubing arising from any difference in gas pressure across it. It has been found that at temperatures below 1500°K the alumina tubing can safely withstand a pressure difference of 1 atmosphere. As the H₂ + argon mixture is flushed, it is pumped through a vacuum pump whose exhaust is directed into the flame of a Meeker burner where the H, is burned. The flame is located under a hood so that the fumes are exhausted to the outside. It was found that this technique was more reliable than attempting to burn the H, + argon mixture alone, since the flow was so small that the flame frequently extinguished itself.

Copper coils have been soldered to the outside of the furnace to provide water cooling. Other coils, part of which are not shown in Figure A-1, have been provided to cool the ends of the furnace so that the "O"-ring seals and CaF, windows will not be damaged. The separate set of heating coils which are shown adjacent to the cooling coils on the left end of the furnace are provided to heat the sample entrance and exit lines to a sufficiently high temperature to prevent condensation of H₂O when it is being studied. In some cases the extra heat is necessary when there is not enough provided by the heating elements inside the furnace. It is seen from Figure A-1 that the sample entrance and exit lines pass through this postion of the furnace.

Temperatures inside the furnace are measured by thermocouples having one leg of Pt-6% Rh and the other leg of Pt-30% Rh. The thermocouples are placed along the furnace at various locations to provide information about the temperature uniformity. Three thermocouples are indicated in Figure A-1, although additional ones have recently been used to provide more information about the temperature profile in the furnace, particularly near the windows of the sample cell and near the "O"-rings close to the ends of the furnace. In order to minimize temperature gradients within the alumina tubing, the temperatures in the regions near the "O"-ring seals are not kept much lower than is necessary for the protection of the seals. Thermocouple wires and connections to the electrical heating element are made through Conax fittings.

The voltage from the center thermocouple is recorded on a Leeds and Northrup strip chart recorder and also serves as the input to a Leeds and Northrup control unit. Voltages from the other thermocouples are measured with a vacuum tube voltmeter having very high input impedance. The controller can be preset to a given voltage corresponding to the desired temperature, and will automatically maintain this temperature after making certain adjustments which depend on the time lag between the hesting coils and the thermocouple, and on the heat capacity of the system. After the furnace has been heated to the desired temperature and the controller adjustments have been mads, the current through the end heaters is controlled manually to provide uniform temperature over the region containing the sample cell.

Both of the sample cells are made of an alloy of Pt-20% Rh which will withstand temperatures as high as 2600°K. The body of each cell is a piece of tubing having a wall thickness of 0.38 mm with flanges, which are 0.25 mm thick and 2.5 cm in diameter, fused to the ends. The diameter of the short cell is 1.3 cm, and the long one is 1.7 cm. Two tubes having approximately 4 mm I.D. are fused to the body of the cell, as shown in Figure A-1, and extend to one end of the furnace where they connect to the gas handling system. One tube serves as the inlet and the other as the outlet for the sample gas.

No information about the thermal coefficient of expansion of the Pt-20% Rh alloy for temperatures above about 1200°K could be found, so in order to calculate the cell length at high temperatures it was assumed that the thermal coefficient at high temperatures was the same as that at lower temperatures. Since the difference in length at the different operating temperatures is small and since it could not be calculated accurately, a single value of cell length is used for all the high temperatures. The shorter cell was the only one used in obtaining data appearing in the present report; its estimated length of 7.75 cm is probably in error by less than $\frac{1}{2}$ 0.05 cm.

Sapphire windows, which are 25 mm in diameter, are clamped against the flanges by the use of washers and bolts made of the same alloy as the body of the cell. Gaskets of the same material, and 0.025 mm thick, are used between the windows and the thin flanges which are sufficiently flexible to bend to the proper shape and make good contact as the windows are tightened. The seal which is formed would not be good for vacuum applications, but the leakage is small since the pressure is the same on both sides of the window. Both the sample gas and the argon are flushed continuously to avoid accumulation of either of these gases in the wrong section; i.e., the sample in the argon section or the argon in the sample cell. Flow rates of approxim rely 5 and 700 cm per minute were used for the sample and argon, rectively.

Since the absorption by sapphire becomes important below approximately 2200 cm $^{-1}$ ($\lambda > 4.5\mu$), the windows are as thin as seems practical. It is essential that the absorption not be large at these frequencies so that the low frequency side of the CO, absorption region can be studied. The absorption by sapphire increases with temperature, so the windows on the short cell, which is heated to 2000° K, are only 0.5 mm thick. Windows 1 mm thick are used on the longer cell since it will not be used at such high temperatures. As well as the need for extra strength, a further reason for using the 1 mm windows instead of the 0.5 mm ones where it is possible, is that the thinner ones produce a slight fringe pattern which can be troublesome. It is necessary to slightly defocus the optics to eliminate the tringes which appear on the spectra in the region near 2350 cm $^{-1}$.

APPENDIX B

GAS HANDLING SYSTEM

The most important purposes and requirements of the gas handling $\ensuremath{\mathsf{system}}$ are:

- To produce samples containing H₂O, CO₂, N₂ and other non-corrosive gases in any desired mixing ratio at pressures from approximately 3 to 1500 mm Hg.
- To continuously flow the sample gas through the sample cell at a known and adjustable rate while the pressure is automatically controlled.
- To flow argon through the section of the furnace surrounding the sample cell at a known and adjustable rate and at the same pressure as the sample.
- To provide a means of measuring the sample pressure with good accuracy.
- To "bleed off" gas from either the argon or sample line after it has passed through the furnace and to direct it into the monitor cell where its infrared spectrum can be obtained.

Two key parts of the gas handling system are the inexpensive pressure regulators which were made for 'se on commarcial gas lines.'

The regulators are shown symbolically by parts 8 and 15 in the diagram of the gas handling system shown in Figure 8-1. The pressure on the downstream side of the regulator is automatically maintained at some value p(con) provided it is less than the pressure on the upstream side. Gas flow through a small orifice is controlled by a plunger which is actuated by a mechanical connection to a disphragm which is approximately 15 cm in diameter. One side of the disphragm is open to the downstream side of the regulator and is, therefore, at the same pressure. The pressure on the other side of the disphragm is defined as the reference pressure, p(ref), and is equal to the atmospheric pressure in the normal operation of the regulator on commercial gas lines. The disphragm is spring-loaded so that a variable force can be applied to it. By varying the force against the disphragm, the difference

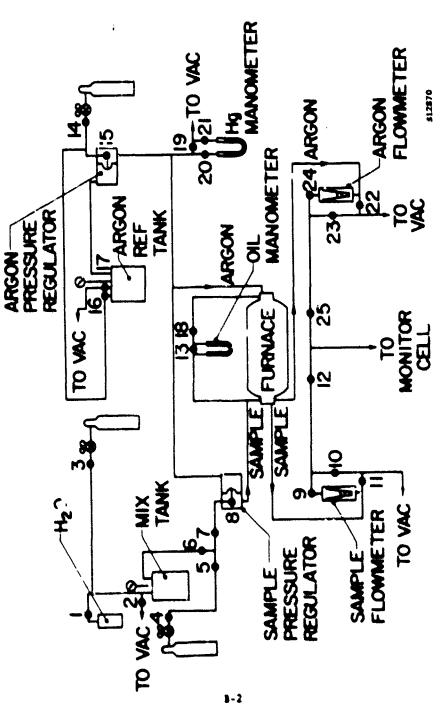


FIGURE 3-1. DIACRAM OF CAS MANDLING SYSTEM

between p(ref) and p(con) is changed. In the normal operation on commercial gas lines p(con) is from 5 to 15 mm Hg greater than p(ref). Without changing the regulator, it is not possible to adjust the force on the diaphragm so that p(ref) and p(con) are equal.

In order to use the regulators in the present investigation, two basic modifications were made. The first modification made it possible to adjust the difference between p(con) and p(ref) so that the two were equal. This was done by attaching a steel plate as a weight to the diaphragm of the regulator. The regulator was then inverted from its normal operating position, and by adjusting the force on the spring against the diaphragm, the difference between p(con) and p(ref) could be adjusted. The difference can now be regulated from approximately -5 mm to +5 mm Hg.

The second modification involved realing the reference side of the regulator and connecting it to a tank, called the reference tank, which has a volume of approximately 6 liters. The purpose of the reference tank is to increase the volume of gas on the reference side of the disphragm so that small leaks and motions of the disphragm will have little effect on the reference pressure. The reference tank can be evacuated or pressurized, and the approximate pressure can be read from a dial type vacuum-pressure gauge. From the discussion of the operation of the system which follows, it can be seen that it is not necessary to know the pressure in the reference tank very accurately.

The difference between p(con) and p(ref) can be adjusted while the system is under vacuum or under pressure by changing the force of the spring against the disphragm by means of an adjustment through a rotating seal. During operation only very small adjustments have been found to be necessary. Because of the large area of the disphragm, the regulator will respond easily to pressure changes which are much less than 0.1 mm Mg.

The operating principles of the gas handling system can best be explained by describing the filling operation. The reference tank, the argon section, and the sample cell are all evacuated, and the valves to the vacuum pumps are all closed. Argon or air is then allowed to flow slowly into the reference tank. As the pressure in the reference tank increases the argon regulator (15) opens and argon flows into the argon section, maintaining a pressure nearly equal to the reference pressure. The argon line is connected to the reference side of the sample pressure regulator (8) so that as the argon pressure increases the regulator opens and sample gas is allowed to flow into the sample section. If the pressures are increased slowly, and if the spring force on the diaphragms of the regulators are properly adjusted, the pressures in the sample section and the argon section will be approximately equal to that in the reference

tank at all times. When the desired pressure is reached valve (16) to the reference tank is closed. Valves (10) and (23) are then opened and needle valves (9) and (24) are adjusted to give the proper flow in the sample and argon sections, respectively. Values of flow rates are read from the flowmeters shown. Valves (10) and (23) are block valves used to stop the gas flow without closing the needle valves, thus avoiding possible damage to them. Valves (11) and (22) are open only when the system is being evacuated in order to pump the gas through the flowmeters. Valves (12) and (25) are also normally closed, and their purpose will be described below.

The small oil manometer which is connected between the sample line and the argon line serves two purposes. Valve (13) is normally closed and valve (18) open so that the manometer reads the difference in pressure between the sample and argon sections. The pressures can easily be equalized by adjusting the spring force on the disphragm of the sample pressure regulator (8). The second purpose of the manometer is that of a safety valve; in case of a mistake in opening or closing of the other valves a large pressure difference cannot be built up between the argon and sample sections. As the pressure difference starts to increase, the oil will flow out of the manometer and into a trap which is not shown in the line. The argon and sample sections are then connected together and the pressures will quickly equalize. When the system is being evacuated, valve (13) is opened in order to maintain nearly equal pressure in the argon and sample sections without the possibility of forcing the oil from the manometer into the traps.

The pressure in the argon section is measured by one of three pressure gauges. The Mg menometer which is shown in Figure 8-1 is used for pressures between 20 and 800 mm Mg. Two other gauges, which are not shown in the figure, are used for other pressure ranges. A Dubrovin is employed for pressures less than 20 mm Mg and a Sourdon type gauge for pressures greater than about 800 mm Mg. Since the sample and argon are maintained at the same pressure, the pressure indicated by the gauges is that of the sample. This is are the measurement of the sample pressure resulting the pressure drops in the gas lines is only important for pressures less than mount 6 or 8 mm Mg for the flow rates used in the present investigation.

Samples can be introduced to the system from remarcial cylinders through valves (4) and (5), or from the mix tank through valve (0). Heny of the CO + N mixtures were purchased profixed so that they could be used directly from the cylinders. Other gas mixtures, including all those that contain N O, were made in the mix tank, which has a volume of about 50 liters and Is lined with glass on the inside to reduce adsorption of

gas on the walls. In order to ensure proper mixing, a mixer has been incorporated in the tank. It is driven through a rotating seal by an electric motor on top of the tank.

The mix tank, small oil manometer, sample regulator, sample flowmeter, and all the other components which might contain H₂O vapor when it is being studied, are enclosed in an oven which can be heated to approximately 140°C. By maintaining this temperature it is possible to study samples containing H₂O vapor at partial pressures as high as approximately 1500 mm Hg without condensation. The lines connecting the sample cell in the furnace to the components enclosed in the oven are insulated and heated by an electric heating wire. The valves and the regulator in the oven can be controlled from outside and the oil manometer and sample flowmeter can be viewed though windows. When studying samples not containing H₂O, the components in the oven are not heated.

When a gas mixture is being produced in the mix tank, each gas is introduced separately, and the pressure is measured after each is introduced. A dial gauge connected to the mix tank gives only approximate pressures, particularly when the tank is hot. More exact values of pressure are measured by a system which is not included in Figure B-1. If the mixture does not contain HaO vapor, the pressures are measured by one of the three gauges used on the argon line. When HaO vapor is included in the mixture, the mix tank is connected to an side of a small glass II-+ 'e containing vacuum pump oil which is enclosed in the oven to preven condensation of the H₀O. The other side of the U-tube is connected to one of the three pressure gauges used on the cagon line. The prossure in the line to the gauge's can be adjusted so that there is no pressure difference between the two sides of the U-tube. The gauges then indicate the pressure in the mix tank. By this technique it is possible to measure pressures in the mix tank with about the same accuracy as in the argon line without heating the pressure gauges.

Other sections of this report contain discussions of the use of the monitor cell to determine the parity of the gas coming from either the argon section or the sample section. To investigate the gas in the argon section, for example, the monitor cell is first evacuated and the gas is introduced through valve (25) with valves (23) and (22) closed. In this manner it is possible to fill the cell with a minimum of disturbance or change in the flow of the gas in the system. By adjusting the opening of valve (24) the flow of argon can be maintained very nearly constant until the pressure in the monitor cell approaches that in the argon section. When the flow stops, it is assumed that the pressure in the monitor cell is equal to that in the argon section. Valve (25) is then closed and the other valves are re-adjusted to give the desired flow rate. In order to investigate the gas in the sample section, a similar procedure is followed by use of valves 9, 10, 11, and 12.

DISTRIBUTION	Number of Copies
Advanced Research Projects Agency Washington 25, D. C.	ž
Institute for Defense Analyses 1666 Connecticut Avenue, N. W. Washington 9, D. C. Attn: aZSD Library	1
University of Chicago Laboratories for Applied Sciences Museum of Science and Industry Chicago 37, Illinois Attn: L. Biberman	1
University of Michigan Institute for Science & Technology P. O. Lox 618 Ann Arbor, Michigan	2
Stanford Research Institute Henlo Park, California	1
Massachusetts Institute of Tachnology Lincoln Laboratories Lexington, Massachusetts Attn: W8461 Office	1

	Number of Copies
General Dynamics/Astronautics	2
P.O. Box 1128	
San Diego 12, California	
Attn: F. Michael	
Dr. A. E. Green	
	_
Bendix Systems Division	1
3300 Plymouth Road	
Ann Arbor, Michigan	
Attn: D. Lowe	
Unches Administr Co	1
Hughes Aircraft Co. 11940 W. Jefferson Blyd.	
Culver City, California	
Attn: S. Borfman	
Attn. 5. Dollmen	
Space Technology Laboratories	1
Space Park	
Redondo Beach, California	
Attn: A. Fulton	
	10
ASTIA	10
Arlington Hall Station	
Arlington 1, Virginia	
Arthur D. Little, Inc.	1
500 Sansome Street	
Sen Francisco, California	
Attn: H. Blau	•
	_
Boeing Aircraft Co.	1
Aerospace Division	
P.O. Box 3/07	
Seattle 24, Washington	
Attn: R. McDonald	
Lockheed Missile & Space Company	1
Sunnyvale, California	
Attn: H. Batten	
Baird-Atomic, Inc.	1
33 University Road	
Cambridge 38, Massachusetts	
Armsten Comparel Comparetion	1
Aerojet-General Corporation	*
Azusa, California Attn: Dr. J. A. Jamieson	
ACCO. Dr. J. A. Jemicaon	

		limber of G
National Bureau of Standard Boulder Laboratories Boulder, Colorado Attn: Dr. D. N. Gates	da .	1
Commending Officer Nevel Ordnonce Test Station Weapons Development Departs China Lake, California Attn: D. K. Moore		ı
Maticual Aeronautics and Sp Goodard Space Flight Center Greenbelt, Haryland		1
U.S. Weather Bureau National Weather Satellite Washington 25, D. G.	Ceater	1
	(Unclassified Reports Only)	
Chief Juperintendent Conedian Armement Research Establishment	& Development	1
P.O. Box 1427		
Queboc, Canada Atta: Dr. G. Cumming	,	
Aerospace Corporation 2400 El Segundo Boulevard El Segundo, California Attn: Dr. G. Sherwin H. Wesseley		3
I. Spiro	•	•
The Rand Corporation 1700 Main Street		3
Santa Monica, California Attn: Dr. S. Passwan		
Dr. D. Deirmendjian		
Denver Research Institute University of Denver Denver, Colorado		1
Atta: D. Murcray		